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(पहला पुनरीक्षण)

Indian Standard

RADIO DISTURBANCE CHARACTERISTICS FOR PROTECTION OF RECEIVERS USED ON BOARD VEHICLES, BOATS AND INTERNAL COMBUSTION ENGINES — LIMITS AND METHODS OF MEASUREMENT

(First Revision)

ICS 33.100.10, 33.10.20

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

December 2010 **Price Group 16**

Electromagnetic Compatibility Sectional Committee, LITD 09

NATIONAL FOREWORD

This Indian Standard (First Revision) which is identical with CISPR 25 : 2008 'Vehicles, boats and internal combustion engines — Radio disturbance characteristics — Limits and methods of measurement for the protection of on-board receivers' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Electromagnetic Compatibility Sectional Committee and approval of the Electronics and Information Technology Division Council.

This standard was originally published in 2001 and was identical to CISPR 25 : 1995. Thereafter, IEC revised it in the year 2002 and 2008. This revision is, therefore, being undertaken to align it with latest CISPR Standard. This standard is designed to protect on-board receivers from disturbances produced by conducted and radiated emission arising in a vehicle. The limits for electromagnetic interference were earlier covered in IS 6842 : 1997 'Limits for electromagnetic interference — Specification (*second revision*)' which has since been withdrawn.

The text of IEC (CISPR) Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60050-161 : 1990 International Electrotechnical Vocabulary (IEV) — Chapter 161: Electromagnetic compatibility	IS 1885 (Part 64/Sec 1 and 2) : 1987 Electrotechnical vocabulary: Part 64 Electromagnetic compatibility, Section 1 General terms, Section 2 Specific terms	Technically Equivalent
CISPR 12 : 2007 Vehicles, motor-boats, and internal combustion engine-driven devices — Radio disturbance characteristics — Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices	IS 6873 (Part 1) : 2009 Limits and methods of measurements of radio disturbance characteristics: Part 1 Vehicles, motorboats and spark ignited engine — Driven devices (*third revision*)	Identical

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
CISPR 16-1-1 : 2006	Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-1: Radio disturbance and immunity measuring apparatus — Measuring apparatus

(*Continued on third cover*)

IS 15040 : 2010
CISPR 25 : 2008

Indian Standard

RADIO DISTURBANCE CHARACTERISTICS FOR PROTECTION OF RECEIVERS USED ON BOARD VEHICLES, BOATS AND INTERNAL COMBUSTION ENGINES — LIMITS AND METHODS OF MEASUREMENT

(First Revision)

1 Scope

This International Standard contains limits and procedures for the measurement of radio disturbances in the frequency range of 150 kHz to 2 500 MHz. The standard applies to any electronic/electrical component intended for use in vehicles, trailers and devices. Refer to International Telecommunications Union (ITU) publications for details of frequency allocations. The limits are intended to provide protection for receivers installed in a vehicle from disturbances produced by components/modules in the same vehicle. The method and limits for a complete vehicle are in Clause 5 and the methods and limits for components/modules are in Clause 6. Only a complete vehicle test can be used to determine the component compatibility with respect to a vehicle’s limit.

The receiver types to be protected are, for example, broadcast receivers (sound and television), land mobile radio, radio telephone, amateur, citizens' radio, Satellite Navigation (GPS, etc.) and Bluetooth. For the purpose of this standard, a vehicle is a machine, which is self-propelled. Vehicles include (but are not limited to) passenger cars, trucks, agricultural tractors and snowmobiles. Annex A provides guidance in determining whether this standard is applicable to particular equipment.

The limits in this standard are recommended and subject to modification as agreed between the vehicle manufacturer and the component supplier. This standard is also intended to be applied by manufacturers and suppliers of components and equipment which are to be added and connected to the vehicle harness or to an on-board power connector after delivery of the vehicle.

This International Standard does not include protection of electronic control systems from radio frequency (RF) emissions, or from transient or pulse-type voltage fluctuations. These subjects are included in ISO publications.

Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, Clause 6 of this standard defines multiple limit levels. The level class to be used (as a function of frequency band) is agreed upon between the vehicle manufacturer and the component supplier.

CISPR 25 defines test methods for use by vehicle manufacturers and suppliers, to assist in the design of vehicles and components and ensure controlled levels of on-board radio frequency emissions.

Vehicle test limits are provided for guidance and are based on a typical radio receiver using the antenna provided as part of the vehicle, or a test antenna if a unique antenna is not specified. The frequency bands that are defined are not applicable to all regions or countries of the world. For economic reasons, the vehicle manufacturer must be free to identify what frequency bands are applicable in the countries in which a vehicle will be marketed and which radio services are likely to be used in that vehicle.

As an example, many vehicle models will probably not have a television receiver installed; yet the television bands occupy a significant portion of the radio spectrum. Testing and mitigating noise sources in such vehicles is not economically justified.

The vehicle manufacturer should define the countries in which the vehicle is to be marketed, then choose the applicable frequency bands and limits. Component test parameters can then be selected from CISPR 25 to support the chosen marketing plan.

The World Administrative Radio communications Conference (WARC) lower frequency limit in region 1 was reduced to 148,5 kHz in 1979. For vehicular purposes, tests at 150 kHz are considered adequate. For the purposes of this standard, test frequency ranges have been generalized to cover radio services in various parts of the world. Protection of radio reception at adjacent frequencies can be expected in most cases.

Annex H defines a qualitative method of judging the degradation of radio communication in the presence of impulsive noise.

Annex I lists work being considered for future revisions.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*
Amendment 1:1997
Amendment 2:1998

CISPR 12:2007, *Vehicles, motorboats, and internal combustion engine-driven devices – Radio disturbance characteristics – Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices.*

CISPR 16-1-1:2006, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*
Amendment 1:2006
Amendment 2:2007

CISPR 16-1-2:2003*, Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Conducted disturbances*
Amendment 1:2004
Amendment 2:2006

CISPR 16-1-4:2007, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Radiated disturbances*
Amendment 1:2007

CISPR 16-2-3:2006, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements*

ISO 11452-4:2005 - *Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4: Bulk current injection (BCI)*

SAE ARP 958.1 Rev D:2003-02 – Electromagnetic Interference Measurement Antennas; Standard Calibration Method

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
absorber lined shielded enclosure (ALSE)
shielded enclosure/screened room with radio frequency-absorbing material on its internal ceiling and walls

3.2
antenna factor
the factor which is applied to the voltage measured at the input connector of the measuring instrument to give the field strength at the antenna

3.3
antenna matching unit
a unit for matching the impedance of an antenna to that of the 50 Ω measuring instrument over the antenna measuring frequency range

3.4
class
a performance level agreed upon by the purchaser and the supplier and documented in the test plan

3.5
component continuous conducted emissions
the noise voltages/currents of a steady-state nature existing on the supply or other leads of a component/module which may cause disturbance to reception in an on-board receiver.

3.6
compression point
the input signal level at which the gain of the measuring system becomes non-linear such that the indicated output deviates from an ideal linear receiving system's output by the specified increment in dB

3.7
device
a machine driven by an internal combustion engine which is not primarily intended to carry persons or goods.

NOTE Devices include, but are not limited to, chainsaws, irrigation pumps, snow blowers, air compressors, and landscaping equipment.

3.8
receiver terminal voltage (antenna voltage)
the voltage generated by a source of radio disturbance and measured in dB (μV) by a radio disturbance measuring instrument conforming to the requirements of CISPR 16

3.9
RF boundary
an element of an EMC test set-up that determines what part of the harness and/or peripherals are included in the RF environment and what is excluded. It may consist of, for example, ANs, filter feed-through pins, RF absorber coated wire, and/or RF shielding

3.10
artificial network (AN) ; line impedance stabilization network (LISN[1])
a network inserted in the supply lead or signal/load lead of apparatus to be tested which provides, in a given frequency range, a specified load impedance for the measurement of *disturbance voltages* and which may isolate the apparatus from the supply or signal sources/loads in that frequency range

[IEV 161-04-05, modified]

3.11
average detector
a detector, the output voltage of which is the average value of the envelope of an applied signal

NOTE The average value must be taken over a specified time interval.

[IEV 161-04-26]

3.12
bandwidth

3.12.1
bandwidth (of an equipment)
the width of a frequency band over which a given characteristic of an equipment or transmission channel does not differ from its reference value by more than a specified amount or ratio

NOTE The given characteristic may be, for example, the amplitude/frequency characteristic, the phase/frequency characteristic or the delay/frequency characteristic.

[IEV 161-06-09, modified]

3.12.2
bandwidth (of an emission or signal)
the width of the frequency band outside which the level of any spectral component does not exceed a specified percentage of a reference level

[IEV 161-06-10]

3.13
broadband emission
an *emission* which has a *bandwidth* greater than that of a particular measuring apparatus or receiver

[IEV 161-06-11, modified]

NOTE An emission which has a pulse repetition rate (in Hz) less than the bandwidth of a particular measuring instrument can also be considered as a broadband emission.

3.14
disturbance suppression
action which reduces or eliminates *electromagnetic disturbance*

[IEV 161-03-22]

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[1] USA

3.15
disturbance voltage; interference voltage (deprecated in this sense)
voltage produced between two points on two separate conductors by an *electromagnetic disturbance*, measured under specified conditions

[IEV 161-04-01]

3.16
electromagnetic environment
the totality of electromagnetic phenomena existing at a given location

[IEV 161-01-01]

3.17
ground (reference) plane
a flat conductive surface whose potential is used as a common reference.

[IEV 161-04-36]

3.18
narrowband emission
an *emission* which has a *bandwidth* less than that of a particular measuring apparatus or receiver

[IEV 161-06-13]

NOTE An emission which has a pulse repetition rate (in Hz) greater than the bandwidth of a particular measuring instrument can also be considered as a narrowband emission.

3.19
peak detector
a detector, the output voltage of which is the peak value of an applied signal

[IEV 161-04-24]

3.20
quasi-peak detector
a detector having specified *electrical time constants* which, when regularly repeated identical *pulses* are applied to it, delivers an output voltage which is a fraction of the peak value of the pulses, the fraction increasing towards unity as the pulse repetition rate is increased

[IEV 161-04-21]

3.21
shielded enclosure; screened room
a mesh or sheet metallic housing designed expressly for the purpose of separating electromagnetically the internal and the external environment

[IEV 161-04-37]

4 Requirements common to vehicle and component/module emissions measurement

4.1 General test requirements and test plan

4.1.1 Categories of disturbance sources (as applied in the test plan)

Electromagnetic disturbance sources can be divided into two main types:

- Narrowband sources (examples of narrowband disturbance sources are vehicle electronic components which include clocks, oscillators, digital logic from microprocessors and displays).
- Broadband sources (examples of broadband disturbance sources are electrical motors and ignition system).

NOTE 1 While most vehicle or electrical/electronic components are a source of both narrowband and broadband disturbances, some may be a source of only one type of disturbance.

NOTE 2 Broadband sources can be classified in short-duration broadband (examples are washer pump, door mirror, electrical windows) and long-duration broadband (examples are front wiper motor, heater blower, engine cooling).

For the purposes of this standard, categorization of the disturbance type is used only in simplifying the testing demands by potentially reducing the number of detectors that shall be used (i.e. eliminating the average detector if the device is known to be broadband-type of source, such as a d.c. brush commutated motor). Otherwise, this standard requires that sources comply with limits based upon both types of measurement detectors and not the type of disturbance.

4.1.2 Test plan

A test plan shall be established for each item to be tested. The test plan shall specify the

- frequency range to be tested,
- the emissions limits,
- antenna types and locations,
- test report requirements,
- supply voltage and other relevant parameters.

The test plan shall define for each frequency band whether the conformance can be obtained with average and peak limits or with average and quasi-peak limits.

4.1.3 Determination of conformance of EUT with limits

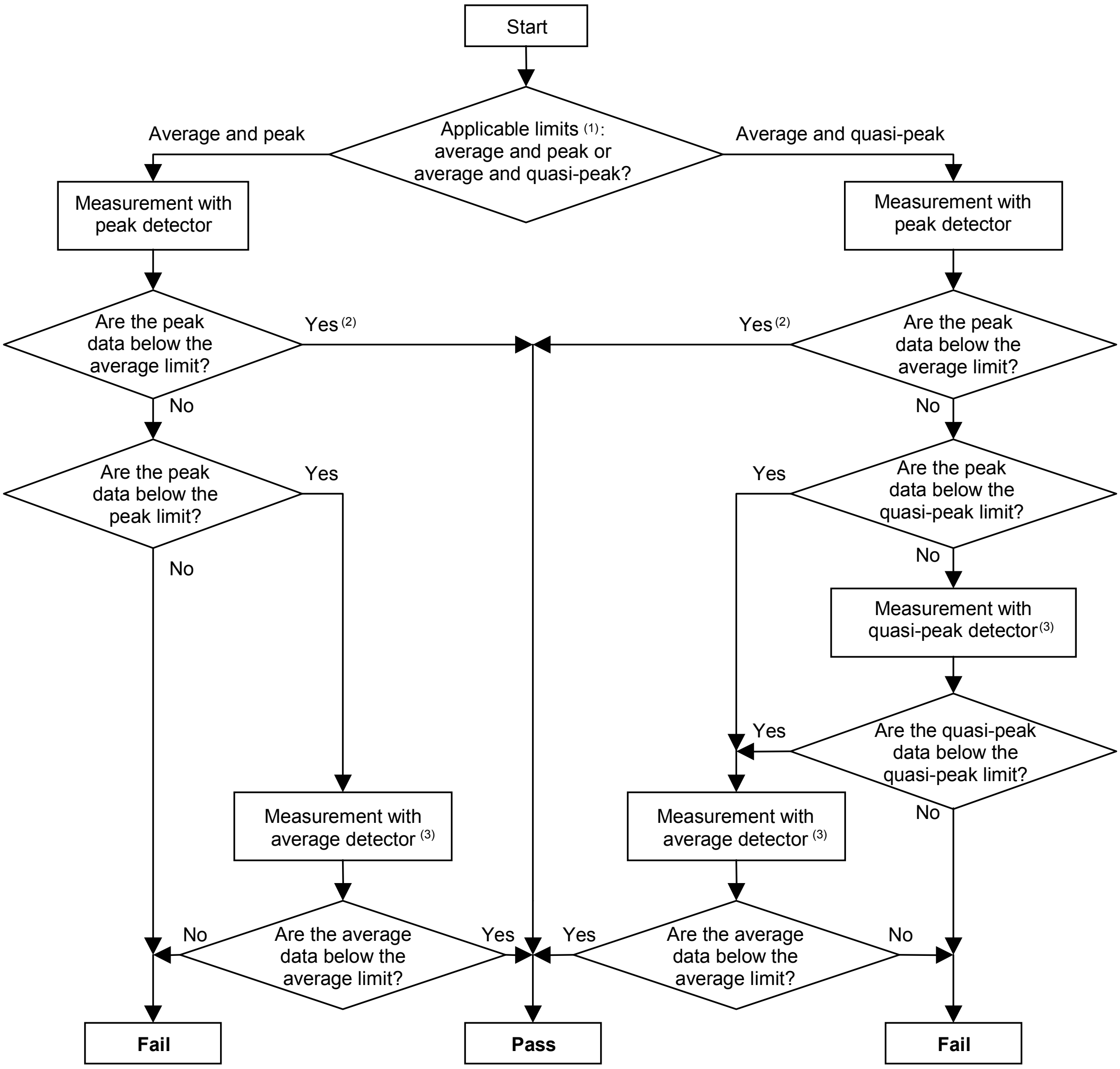
In all cases the EUT shall conform with the average limit.

The EUT shall also conform with either peak or quasi-peaks limits as follows.

- For frequencies where both peak and quasi-peak limits are defined, the EUT shall conform with either the peak or the quasi-peak limits (as defined in the test plan).
- For frequencies where only peak limits are defined, the EUT shall conform with the peak limit.

The general procedure applicable for all frequency bands is described in Figure 1.

The limits given in this standard take into account uncertainties.


Start
Applicable limits (1): average and peak or average and quasi-peak?
Average and peak
Average and quasi-peak
Measurement with peak detector
Measurement with peak detector
Are the peak data below the average limit?
Yes (2)
Yes (2)
Are the peak data below the average limit?
No
No
Are the peak data below the peak limit?
Yes
Yes
Are the peak data below the quasi-peak limit?
No
No
Measurement with quasi-peak detector (3)
Yes
Are the quasi-peak data below the quasi-peak limit?
No
Measurement with average detector (3)
Measurement with average detector (3)
No
Are the average data below the average limit?
Yes
Yes
Are the average data below the average limit?
No
Fail
Pass
Fail

NOTE 1 The conformance should normally be obtained by compliance to both average and peak limits or both average and quasi-peak limits unless the test plan defines that conformance can be obtained by compliance to the single appropriate limit) *(*depending on the case, peak, or average, or quasi-peak*)*.

NOTE 2 Because measurement with peak detector is always higher or equal to measurement with average detector and applicable peak limit is always higher or equal to applicable average limit, this single detector measurement can lead to a simplified and quicker conformance process.

NOTE 3 This flow-chart is applicable for each individual frequency, e.g. only frequencies that are above the applicable limit need be remeasured with average or quasi-peak detector.

Figure 1 – Method of determination of conformance for all frequency bands

4.1.4 Operating conditions

Different operating conditions of the EUT can influence emission measurement results. When performing component/module tests, the EUT shall be made to operate under typical loading and other conditions as in the vehicle such that the maximum emission state occurs. The operating conditions shall be specified in the test plan.

To ensure correct operation of components/modules during test, a peripheral interface unit shall be used which simulates the vehicle installation. Depending on the intended operating modes, all significant sensor and actuator leads of the EUT shall be connected to a peripheral interface unit. The peripheral interface unit shall be capable of controlling the EUT in accordance with the test plan.

The peripheral interface unit may be located internal or external to the shielded enclosure. If located in the shielded enclosure, the disturbance levels generated by the peripheral interface unit shall be at least 6 dB below the test limits specified in the test plan.

4.1.5 Test report

The report shall contain the information agreed upon by the customer and the supplier, e.g.

- sample identification,
- date and time of test,
- bandwidth,
- step size,
- required test limit,
- ambient data
- test data.

4.2 Shielded enclosure

The ambient electromagnetic noise levels shall be at least 6 dB below the limits specified in the test plan for each test to be performed. The shielding effectiveness of the shielded enclosure shall be sufficient to ensure that the required ambient electromagnetic noise level requirement is met.

NOTE Although there will be reflected energy from the interior surfaces of the shielded enclosure, this is of minimal concern for the measurement of conducted disturbances because of the direct coupling of the measuring instrument to the leads of the EUT. The shielded enclosure may be as simple as a suitably grounded bench-top screened cage.

4.3 Absorber-lined shielded enclosure (ALSE)

For radiated emission measurements, however, the reflected energy can cause errors of as much as 20 dB. Therefore, it is necessary to apply RF absorber material to the walls and ceiling of a shielded enclosure that is to be used for radiated emissions measurements. No absorber material shall be placed on the floor for vehicle or component level tests. The following ALSE requirements shall also be met for performing radiated RF emissions measurements.

4.3.1 Reflection characteristics

Performance of the absorption material shall be greater than or equal to 6 dB in the 70 MHz to 2 500 MHz frequency range.

NOTE A test method is described in IEEE STD 1128-1998: *IEEE recommended practice for radio frequency (RF) absorber – Evaluation in the range of 30 MHz to 5 GHz.*

4.3.2 Size

For radiated emissions tests, the shielded enclosure shall be of sufficient size to ensure that neither the vehicle/EUT nor the test antenna shall be closer than 1 m from the walls or ceiling, or to the nearest surface of the absorber material used thereon.

4.3.3 Objects in ALSE

For radiated emissions measurements in particular, the ALSE shall be cleared of all items not pertinent to the tests. This is required in order to reduce any effect they may have on the measurement. Included are unnecessary equipment, cable racks, storage cabinets, desks, chairs, etc. Personnel not actively involved in the test shall be excluded from the ALSE.

4.4 Measuring instrument

The measuring instrument shall comply with the requirements of CISPR 16-1-1. Either manual or automatic frequency scanning may be used. However Annex D of CISPR 16-2-3 explains the differences between the CISPR AV detector and an AV detector (complying with CISPR 16-1:1999). For the purpose of this standard either detector may be used, since the pulse repetition rate for internal combustion engines is above 10 Hz.

NOTE 1 Spectrum analysers and scanning receivers are particularly useful for disturbance measurements. The peak detection mode of spectrum analysers and scanning receivers provides a display indication which is never less than the quasi-peak indication for the same bandwidth. It may be convenient to measure emissions using peak detection because of the faster scan possible than with quasi-peak detection.

NOTE 2 A preamplifier may be used between the antenna and measuring instrument in order to achieve the 6 dB noise floor requirements. If a preamplifier is used to achieve the 6 dB noise floor requirement, the laboratory should establish a procedure to avoid overload of the preamplifier, such as using a step attenuator.

NOTE 3 In particular cases, because of very low average detector limits and/or instrumentation limitations, the 6 dB noise floor requirements may not be fulfilled. In this case and if an appropriate preamplifier has been used, alternatives such as RBW/BW reduction with appropriate step size changes may be used. These measures should be documented in the test report.

4.4.1 Spectrum analyser parameters

The scan rate of the spectrum analyser shall be adjusted for the CISPR frequency band and detection mode used.

Spectrum analysers may be used for performing compliance measurements to this standard providing the precautions cited in CISPR 16-1-1 on the use of spectrum analysers are adhered to and that the broadband emissions from the product being tested have a repetition frequency greater than 20 Hz.

The minimum scan time and recommended bandwidth are listed in Table 1.

The bandwidth of the spectrum analyser shall be chosen such that the noise floor is at least 6 dB lower than the applicable limits.

NOTE See 4.4, Notes 2 and 3.

Table 1 – Spectrum analyser parameters

Service / Frequency range		Peak detection		Quasi-peak detection		Average detection	
	MHz	RBW at -3 dB	Scan time	RBW at -6 dB	Scan time	RBW at -3 dB	Scan time
AM broadcast and mobile services	0,15 - 30	9/10 kHz	10 s / MHz	9 kHz	200 s / MHz	9/10 kHz	10 s / MHz
FM broadcast	76 - 108	100/120 kHz	100 ms / MHz	120 kHz	20 s / MHz	100/120 kHz	100 ms / MHz
Mobile services	30 - 1 000						
TV Band I	41- 88						
TV Band III	174 - 230						
TV Band IV/V	470- 890						
DAB	171- 245						
DTTV	470 - 770	100/120 kHz	100 ms / MHz	Does not apply	Does not apply	100/120 kHz	100 ms / MHz
Mobile service	1 000 - 2 500	100/120 kHz	100 ms / MHz	Does not apply	Does not apply	100/120 kHz	100 ms / MHz
GPS L1 civil	1 567 – 1 583	Does not apply	Does not apply	Does not apply	Does not apply	9/10 kHz	1 s / MHz

When a spectrum analyser is used for measurements, the video bandwidth shall be at least three times the resolution bandwidth (RBW).

4.4.2 Scanning receiver parameters

The dwell time of the scanning receiver shall be adjusted for the CISPR frequency band and detection mode used. The minimum dwell time, maximum step size and recommended bandwidth (BW) are listed in Table 2.

The bandwidth of the scanning receiver shall be chosen such that the noise floor is at least 6 dB lower than the applicable limits.

NOTE See 4.4, Notes 2 and 3.

Table 2 – Scanning receiver parameters

Service / Frequency range MHz		**Peak detection**			**Quasi-peak detection**			**Average detection**		
		BW at -6 dB	**Step size**	**Dwell time**	**BW at -6 dB**	**Step size**	**Dwell time**	**BW at -6 dB**	**Step size**	**Dwell time**
AM broadcast and mobile services	0,15 - 30	9 kHz	5 kHz	50 ms	9 kHz	5 kHz	1 s	9 kHz	5 kHz	50 ms
FM broadcast	76 - 108	120 kHz	50 kHz	5 ms	120 kHz	50 kHz	1 s	120 kHz	50 kHz	5 ms
Mobile services	30 to 1 000									
TV Band I TV Band III TV Band IV/V	41 – 88 174 – 230 470 – 890									
DAB	171 - 245									
DTTV	470 - 770	120 kHz	50 kHz	5 ms	Does not apply	Does not apply	Does not apply	120 kHz	50 kHz	5 ms
Mobile service	1 000 - 2 500	120 kHz	50 kHz	5 ms	Does not apply	Does not apply	Does not apply	120 kHz	50 kHz	5 ms
GPS L1 civil	1 567 – 1 583	Does not apply	Does not apply	Does not apply	Does not apply	Does not apply	Does not apply	9 kHz	5 kHz	5 ms
NOTE For emissions generated by brush commutator motors without an electronic control unit, the maximum step size may be increased up to 5 times the bandwidth.										

4.5 Power supply

The power supply shall have adequate regulation to maintain the supply voltage U_s within the ranges specified:

Vehicle tests: Ignition on, engine off

$$U_s = \left(12^{+2}_{-1}\right) \text{V for systems with 12 V nominal supply voltage}$$

$$U_s = \left(24^{+4}_{-2}\right) \text{V for systems with 24 V nominal supply voltage}$$

Vehicle tests: Engine running

$$U_s = \left(13^{+3}_{-0}\right) \text{V for systems with 12 V nominal supply voltage}$$

$$U_s = \left(26^{+6}_{-0}\right) \text{V for systems with 24 V nominal supply voltage}$$

NOTE Most of the vehicle tests will be performed without the engine running, but with the ignition switched on, therefore care must be taken to ensure that the battery is sufficiently well charged.

Component/module tests:

Unless otherwise stated in the test plan the values below shall be used.

$$U_s = \left(13\,^{+1}_{-1}\right) \text{ V for systems with 12 V nominal supply voltage}$$

$$U_s = \left(26\,^{+2}_{-2}\right) \text{ V for systems with 24 V nominal supply voltage}$$

The power supply shall also be adequately filtered such that the RF noise produced by the power supply is at least 6 dB lower than the limits specified in the test plan.

When specified in the test plan, a vehicle battery shall be connected in parallel with the power supply.

5 Measurement of emissions received by an antenna on the same vehicle

5.1 Antenna measuring system

5.1.1 Type of antenna

An antenna of the type to be supplied with the vehicle shall be used as the measurement antenna for the bands for which it is designed to be used for radio reception.

If no antenna is to be furnished with the vehicle (as is often the case with a mobile radio system), the antenna types in Table 3 shall be used for the test. The antenna type and location shall be included in the test plan.

If an active antenna is used, the noise floor of the measured signal at the radio antenna connector may increase (see also the note in 5.3).

Table 3 – Antenna types

Frequency MHz	Antenna type
0,15 to 6,2	1 m monopole
26 to 54	Loaded quarter-wave monopole
68 to 1 000	Quarter-wave monopole
1 000 to 2 500	As recommended by the vehicle manufacturer

5.1.2 Measuring system requirements

5.1.2.1 Broadcast bands

For each band, the measurement shall be made with instrumentation which has the following specified characteristics.

5.1.2.1.1 AM broadcast:

Long wave (0,15 MHz to 0,3 MHz)

Medium wave (0,53 MHz to 1,8 MHz)

Short wave (5,9 MHz to 6,2 MHz)

The measuring system shall have the following characteristics:

- output impedance of impedance matching equipment: 50 Ω resistive;
- gain: The gain (or attenuation) of the measurement antenna system shall be known with an accuracy of ± 0,5 dB. The gain of the equipment shall remain within a 6 dB envelope for each frequency band as shown in Figure 2. Verification shall be performed in accordance with Annex B;

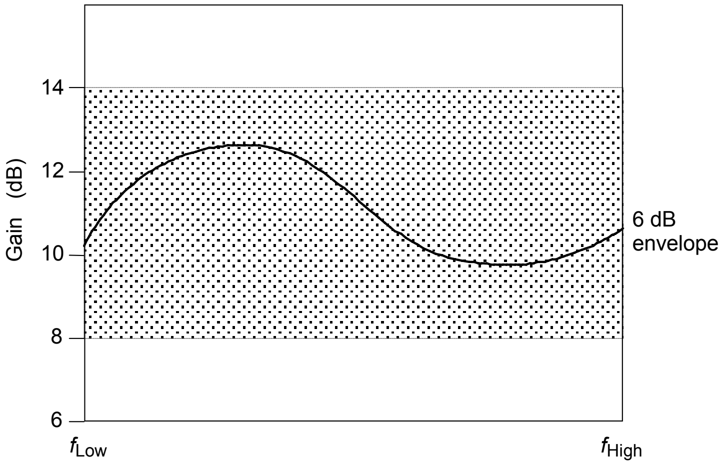


Figure 2 – Example of gain curve

- **compression point**: The 1 dB **compression point** shall occur at a sine wave voltage level greater than 60 dB(μV);
- measurement system noise floor: The noise floor of the combined equipment including measuring instrument, impedance matching equipment, and preamplifier (if used) shall be at least 6 dB lower than the applicable limits;
- dynamic range: from the noise floor to the 1 dB **compression point**;
- input impedance: the impedance at the input of the matching network shall have a resistance of at least 100 kΩ in parallel with a maximum capacitance of 10 pF.

5.1.2.1.2 FM broadcast (76 MHz to 108 MHz) and TV broadcast

Measurements shall be taken with a measuring instrument which has an input impedance of 50 Ω. If the standing wave ratio (SWR) is greater than 2:1 an input matching network shall be used. Appropriate correction shall be made for any attenuation/gain of the matching unit.

5.1.2.2 Mobile services (26 MHz to 2 500 MHz)

The test procedure assumes a 50 Ω measuring instrument and a 50 Ω antenna in the frequency range 26 MHz to 2 500 MHz. If a measuring instrument and an antenna with differing impedances are used, an appropriate network and correction factor shall be used.

5.2 Method of measurement

The disturbance voltage shall be measured at the receiver end of the antenna coaxial cable using the ground contact of the connector as reference. The antenna connector shall be grounded to the housing of the on-board radio. The radio housing shall be grounded to the vehicle body using the production harness. A coaxial bulkhead connector shall be used for connection to the measuring instrument outside the shielded room. See Figure 3. In the case of an active vehicle antenna, which is fed by the radio via the antenna cable (phantom network), a decoupling network similar to that used in the radio shall be installed at the antenna connector to feed the active antenna from the vehicle supply voltage.

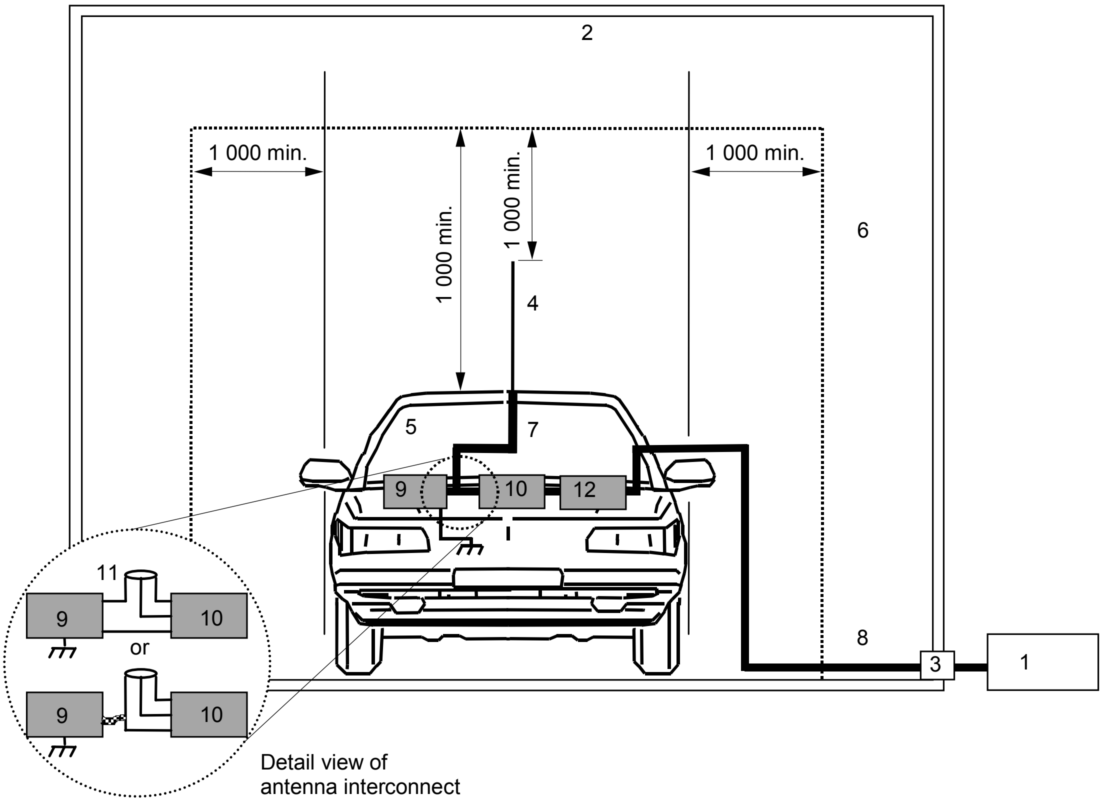
When making measurements in the AM broadcast bands (LW, MW, SW), the vehicle/matching unit ground and ground of the ALSE shall be electrically isolated from each other by means such as an isolation transformer, sheath-current suppressor, battery-powered measurement instrumentation, fiber optics, etc. Appropriate correction shall be made for the insertion loss of any isolation network. (See Annex C for an example of a sheath-current suppressor.)

NOTE The use of a high-quality coaxial cable e.g. double-shielded cable for connection to the measuring instrument is recommended as well as the use of ferrite rings on the cable for suppression of surface currents.

Some vehicles may allow a receiver to be mounted in several locations (e.g. under the instrument panel, under the seat, etc.). In these cases a test shall be carried out as specified in the test plan for each receiver location.

When vehicle measurements are made without the engine running, the power supply of 4.5 shall be used, when needed, to maintain the system voltage within its required range.

Dimensions in millimetres



Key

1	Measuring instrument
2	ALSE
3	Bulkhead connector
4	Antenna (see 5.1)
5	Vehicle
6	Typical absorber material
7	Antenna coaxial cable
8	High-quality coaxial cable e.g. double-shielded (50 Ω)
9	Housing of on-board radio
10	Impedance matching unit (when required)
11	Modified coaxial "T" connector
12	AM broadcast band ground isolation network (when required)

Figure 3 – Vehicle-radiated emissions – Example for test layout (end view with monopole antenna)

5.3 Examples of limits for vehicle radiated disturbances

It is recommended for acceptable radio reception in a vehicle using typical radio receivers, that the disturbance voltage at the end of the antenna cable should not exceed the values shown in Table 4. Where different receivers are used or different coupling models for the propagation of disturbances are valid, the limits may be changed and detailed in the vehicle manufacturer's own specification.

Table 4 – Example for limits of disturbance – Complete vehicle

Service / Band [a]	**Frequency** MHz	**Terminal disturbance voltage at receiver antenna terminal** in **dB** (μV)		
		Peak	**Quasi-peak**	**Average**
BROADCAST				
LW [b]	0,15 - 0,30	26	13	6
MW [b]	0,53 - 1,8	20	7	0
SW [b]	5,9 - 6,2	20	7	0
FM [b]	76 - 108	26	13	6
TV Band I [c]	41 - 88	16	-	6
TV Band III [c]	174 - 230	16	-	6
DAB III	171 - 245	10	-	0
TV Band IV/V [c]	468 - 944	16	-	6
DTTV	470 - 770	20 [d]	-	10 [d]
DAB L band	1 447 – 1 494	10	-	0
SDARS	2 320 – 2 345	16	-	6
MOBILE SERVICES				
CB [b]	26 - 28	20	7	0
VHF [b]	30 - 54	20	7	0
VHF [b]	68 - 87	20	7	0
VHF [b]	142 -175	20	7	0
Analogue UHF [b]	380 - 512	20	7	0
RKE [f]	300 - 330	20	-	6
RKE [f]	420 - 450	20	-	6
Analogue UHF [b]	820 - 960	20	7	0
GSM 800	860 - 895	26	-	6
EGSM/GSM 900	925 - 960	26	-	6
GPS L1 civil [e]	1 567 – 1 583	-	-	0
GSM 1800 (PCN)	1 803 – 1 882	26	-	6
GSM 1900	1 850 – 1 990	26	-	6
3G / IMT 2000	1 900 – 1 992	26	-	6
3G / IMT 2000	2 010 – 2 025	26	-	6
3G / IMT 2000	2 108 – 2 172	26	-	6
Bluetooth/802.11	2 400 – 2 500	26	-	6

[a] LW: Long wave, MW: Medium wave, SW: Short wave (amplitude modulation, AM)
VHF: Very high frequency, UHF: Ultra high frequency (frequency modulation, FM)
DAB: Digital audio broadcasting, TV: Television, DTTV: Digital Terrestrial Television
RKE: Remote keyless entry, GPS: Global positioning system, GSM: Global system mobile
3G: Third generation

[b] In this analogue service the peak and quasi-peak limits can be relaxed by 6 dB for short duration disturbances (e.g. short duration PK (or QPK) limit = PK (or QPK) limit + 6 dB).

[c] Analogue TV only.

[d] This limit is less stringent than the analogue limit and should only be applied where analogue TV is no longer in use.

[e] The bandwidth and frequency steps to be used for the GPS L1 civil band are respectively 9 kHz and 5 kHz rather than the bandwidth and frequency steps defined in Table 1 and Table 2 for services above 30 MHz.

[f] RKE limits are defined over a large frequency band. Any modification of the average limit around the operating frequency due to sensitivity of RKE systems should be defined in the test plan.

NOTE 1 Stereo signals may be more susceptible to disturbance than monaural signals in the FM broadcast band. This phenomenon has been factored into the FM (76 MHz to 108 MHz) limits.

NOTE 2 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Level dB(µV)

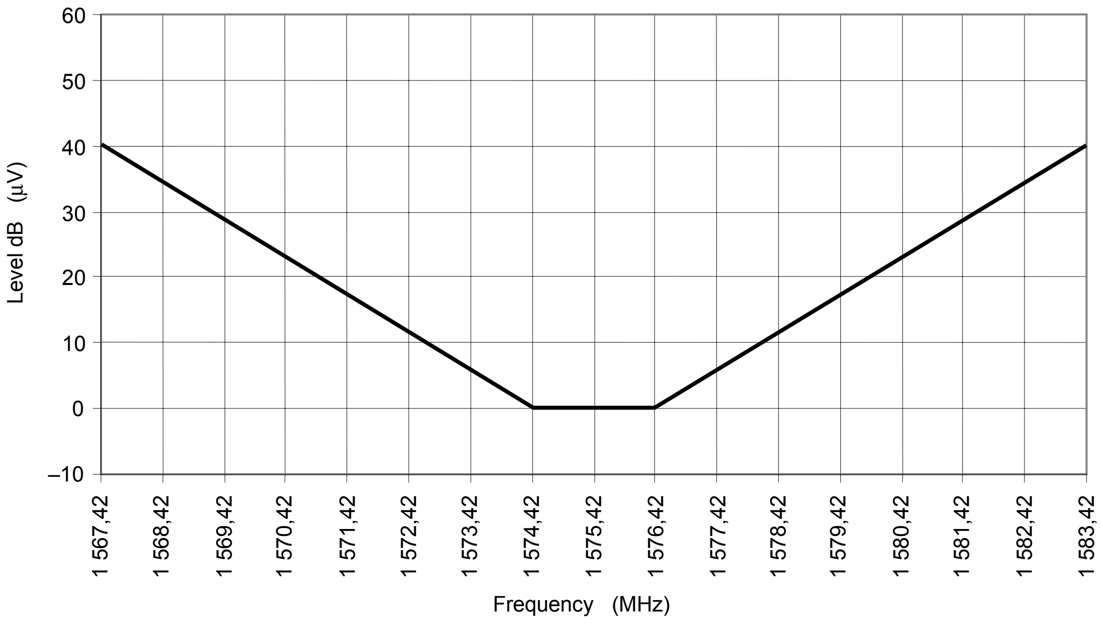


Figure 4 – Average limit for radiated disturbances from vehicles GPS band 1 567,42 to 1 583,42 MHz

NOTE If an active antenna is used, the noise floor may increase. The additional noise floor depends on the type of antenna and must be subtracted from the measured value to determine the real value of the disturbance using the following formula (all terms in µV):

$$U_{real\ Disturbance} = \sqrt{U^2_{Measured} - U^2_{Antenna\ noise}} \qquad (1)$$

A relaxation of the limit because of the active antenna noise floor does not guarantee compliance. Subsequent changes to the active antenna design may result in non-compliance. This topic remains under study. Annex D describes a method to determine the noise floor of an active antenna.

6 Measurement of components and modules

6.1 Test equipment

6.1.1 Ground plane

The ground plane shall be defined as the top metallic surface of the test bench/table.

The ground plane shall be made of 0,5 mm thick (minimum) copper, brass, bronze or galvanized steel.

The minimum size of the ground plane for conducted emissions shall be 1 000 mm × 400 mm.

The minimum width of the ground plane for radiated emissions shall be 1 000 mm. The minimum length of the ground plane for radiated emissions shall be 2 000 mm, or underneath the entire equipment plus 200 mm, whichever is larger.

The height of the ground plane (test bench) shall be (900 ± 100) mm above the floor.

The ground plane shall be bonded to the walls or the floor of the shielded enclosure such that the d.c. resistance shall not exceed 2,5 mΩ. The distance from the edge of the ground strap to the edge of the next strap shall not be greater than 300 mm. The maximum length to width ratio for the ground straps shall be 7:1.

NOTE Because of resonances of the ground plane the location, width and length of the bond straps may influence the measurement results. A sufficient number of low inductive bond straps are necessary to ensure a low impedance connection to the shielded room.

6.1.2 Power supply and AN

For the tests defined in 6.2, 6.3, 6.4, 6.5 and 6.6, each EUT power supply lead shall be connected to the power supply through an artificial network. For the TEM cell emissions tests of 6.5, an AN with a coaxial connector will facilitate connection to the TEM cell EUT power connector. The AN shall have a nominal 5 µH inductance. The impedance characteristics and a suggested schematic are shown in Annex E.

Power supply is assumed to be negative ground. If the EUT utilizes a positive ground then the test set-ups shown in the Figures need to be adapted accordingly. Depending on the intended EUT installation in the vehicle:

- EUT remotely grounded (vehicle power return line longer than 200 mm): two artificial networks are required, one for the positive supply line and one for the power return line.
- EUT locally grounded (vehicle power return line 200 mm or shorter): one artificial network is required, for the positive supply.

The AN(s) shall be mounted directly on the ground plane. The case(s) of the AN(s) shall be bonded to the ground plane.

The power supply return shall be connected to the ground plane (between the power supply and the AN(s)).

The measuring port of the AN not connected to the measuring instrument shall be terminated with a 50 Ω load.

6.1.3 Load simulator

The load simulator includes sensors and actuators, and terminates the test harness connected to the EUT.

To ensure sufficient reproducibility the same termination must be used for each measurement either by using special termination equipment (e.g. artificial networks, filters) – located at the RF boundary – or by using the same load simulator.

6.1.4 Signal/control line filters

In the TEM cell test method using the coaxial connectors for EUT leads each lead shall pass through a filter which has impedance characteristics similar to that of the AN defined above.

The attenuation of the filters shall be specified for the whole frequency range of the intended component/module test (see 6.2 to 6.6) according to the requirements shown in Figure 5. The minimum attenuation shall be more than 40 dB from 30 MHz up to the upper cut-off frequency (f_c), which depends on the intended test method. Figure 5 shows e.g. an upper cut-off frequency (f_c) of the chosen test method of 400 MHz.

NOTE Other low pass RF filter configurations may be used if the filter characteristics are not applicable to special wanted signals of the EUT's inputs or outputs (e.g. high speed network data interfaces). The filters shall be specified in the test plan.

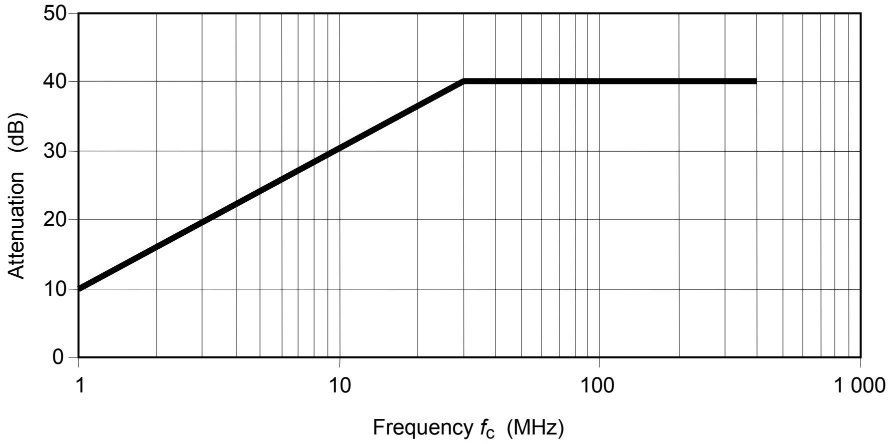


Figure 5 – Example for the required minimum attenuation of the signal / control line filters

6.2 Conducted emissions from components/modules – Voltage method

6.2.1 General

Voltage measurements are able to characterize the emissions on single leads only. The test method is not usable to characterize the radiated emission transmitted e.g. by different antenna structures on the printed board of electronic components or to characterize the efficiency of shielding. Therefore, voltage measurements are not able to characterize the complete EUT emission. At lower frequencies (e.g. in the AM-bands) voltage measurements usually ensure more dynamic range than radiated measurements.

6.2.2 Ground plane arrangement

6.2.2.1 Test set-up

6.2.2.1.1 Location of the EUT

The EUT shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the ground plane.

The case of the EUT shall not be grounded to the ground plane unless it is intended to simulate the actual vehicle configuration.

All sides of the EUT shall be at least 100 mm from the edge of the ground plane. In the case of a grounded EUT, the ground connection point shall also have a minimum distance of 100 mm from the edge of the ground plane.

6.2.2.1.2 Location of the test harness

The power supply line(s) between the connector of the AN(s) and the connector(s) of the EUT (l_p) shall have a standard length of $\left(200\ ^{+200}_{\ \ 0}\right)$ mm.

The harness shall be placed in a straight line on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the ground plane.

If, for particular EUTs (multi-connectors, special connectors, etc.), this standard length for the power supply line(s) cannot be met, the minimum necessary length to be used shall be defined in the test plan. This minimum length shall satisfy the requirement of $f_c \geq 108$ MHz, or the measurements shall be limited to f_c.

The following equation defines f_c :

$$f_c \approx 30 / l_P \tag{2}$$

where

f_c is the frequency in MHz

l_p is the length in m

(This equation is based on $l_p \leq \lambda_{min} / 10$).

To minimize the coupling between power and input/output leads, the space between those lead types shall be maximized (≥ 200 mm from or perpendicular to the power supply lines connecting the AN(s) and the EUT).

The total length of the test harness (excluding power lines) shall not exceed 2 m. The wiring type is defined by the actual system application and requirement.

All leads and cables shall be located at a minimum distance of 100 mm from the edge of the ground plane.

6.2.2.1.3 Location of the load simulator

Preferably, the load simulator shall be placed directly on the ground plane. If the load simulator has a metallic case, this case shall be bonded to the ground plane.

NOTE Alternatively, the load simulator may be located adjacent to the ground plane (with the case of the load simulator bonded to the ground plane) or outside of the test chamber, provided the test harness from the EUT passes through an **RF boundary** bonded to the ground plane.

When the load simulator is located on the ground plane, the d.c. power supply lines of the load simulator shall be connected directly to the power supply and not through the AN(s).

6.2.2.2 Test procedure

The general arrangement of the disturbance source (EUT), connecting harnesses, etc. represents a standardised test condition. Any deviations from the standard test harness length, etc. shall be agreed upon prior to testing and recorded in the test report.

The EUT shall be made to operate under typical loading and other conditions as in the vehicle such that the maximum emission state occurs. These operating conditions must be clearly defined in the test plan to ensure supplier and customer perform identical tests.

- For EUT remotely grounded (vehicle power return line longer than 200 mm), the voltage measurements shall be made on each lead (supply and return) relative to the ground plane.
- For EUT locally grounded (vehicle power return line 200 mm or shorter), voltage measurements on power supply leads shall be made relative to the ground plane.
- Generators/alternators shall be loaded with a battery and parallel resistor combination, and connected to the artificial network in the manner shown in Figure 8. The load current, operating speed, harness length and other conditions shall be defined in the test plan.

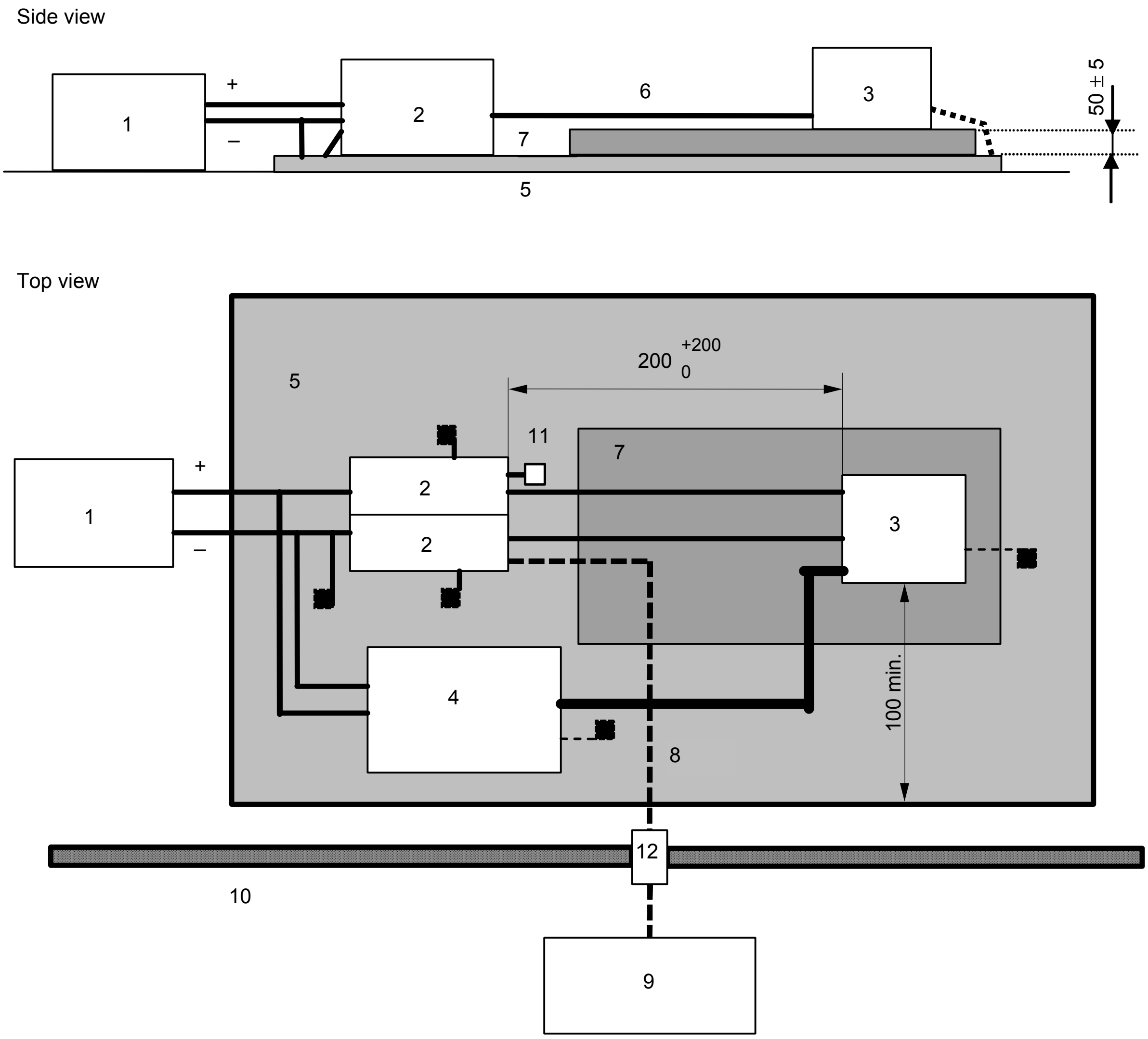
The conducted emissions on power lines are measured successively on positive power supply and power return by connecting the measuring instrument on the measuring port of the related AN, the measuring port of the AN in the other supply lines being terminated with a 50 Ω load.

NOTE For EUT's with multiple positive power supply connections and/or multiple power return connections, the measurements (on power supply and on power return) may be performed with all power supply connections tied together at the AN and all power return connections tied together at the other AN.

The configuration shall be defined in the test plan.

For voltage measurements, the arrangement of the EUT and measuring equipment shall be as shown in Figures , 6, 7 8 and 9 depending on the intended EUT installation in the vehicle.

Dimensions in millimetres – not to scale



Key

1 Power supply (may be placed on the ground plane)

2 Artificial network

3 EUT (housing grounded if required in test plan)

4 Load simulator (metallic casing grounded if required in test plan)

5 Ground plane

6 Power supply lines

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

10 Shielded enclosure

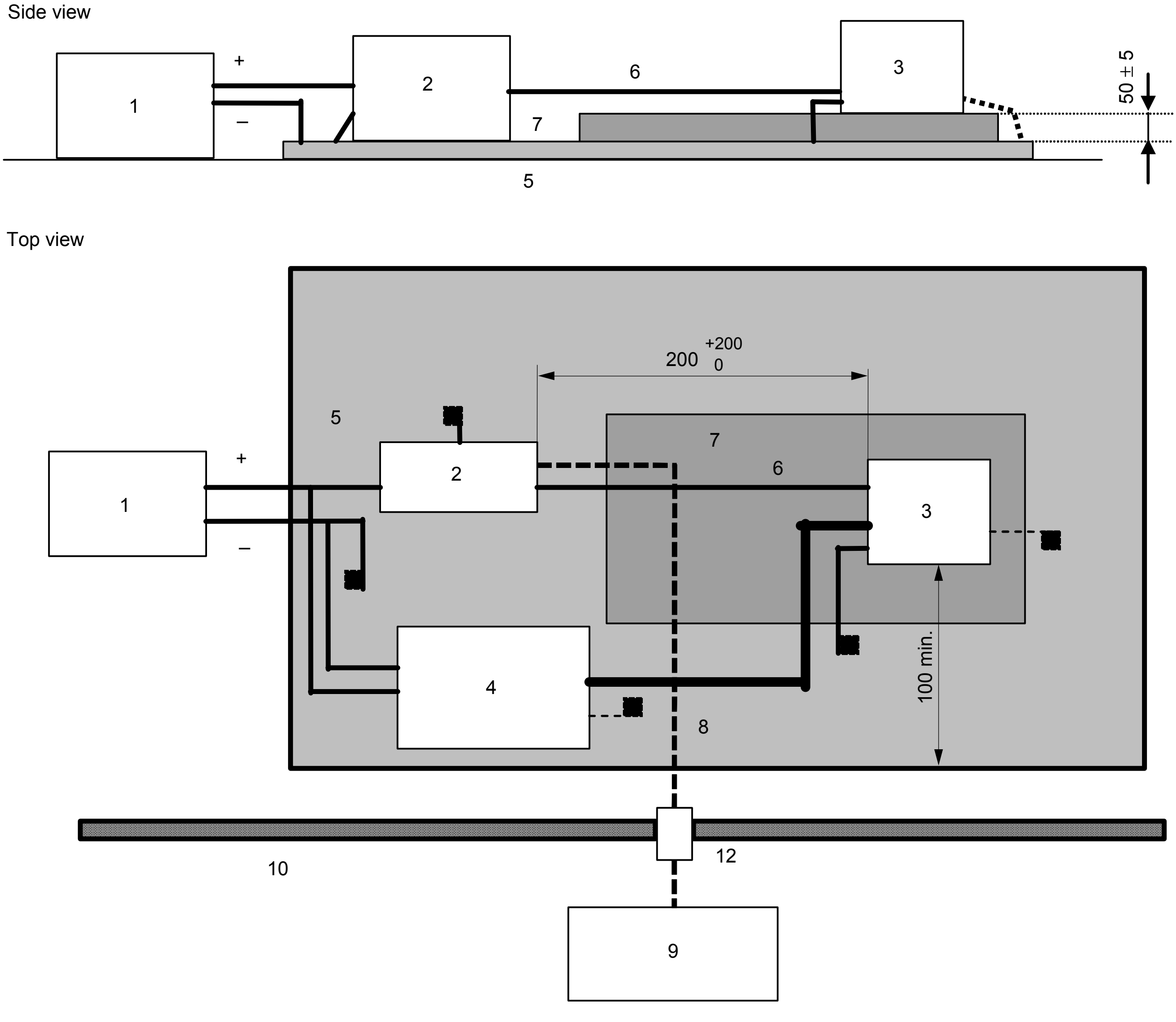
11 50 Ω load

12 Bulkhead connector

NOTE The EUT housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 6 – Conducted emissions – EUT with power return line remotely grounded.

Dimensions in millimetres – not to scale



Key

1 Power supply (may be placed on the ground plane)

2 Artificial network

3 EUT (housing grounded if required in test plan)

4 Load simulator (metallic casing grounded if required in test plan)

5 Ground plane

6 Power supply line

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

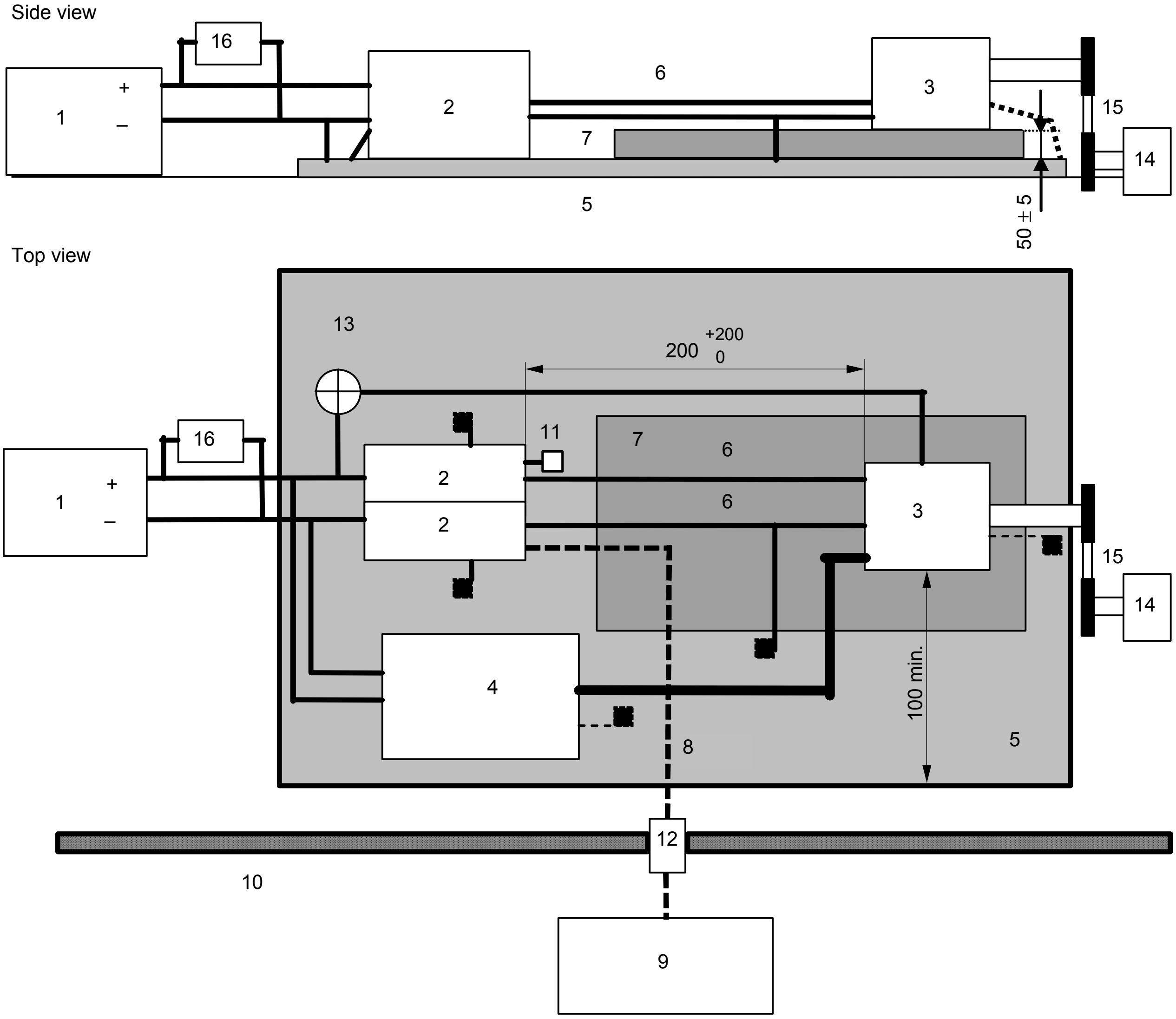
10 Shielded enclosure

12 Bulkhead connector

NOTE The EUT housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 7 – Conducted emissions – EUT with power return line locally grounded

Dimensions in millimetres – not to scale



Key

1 Battery (may be placed on the ground plane)

2 Artificial network

3 EUT

4 Load simulator (metallic casing grounded if required in test plan)

5 Ground plane

6 Power supply lines

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$) – typically not installed

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

10 Shielded enclosure

11 50 Ω load

12 Bulkhead connector

13 Indicator lamp/control resistor (if applicable)

14 Motor (Air/Low Emissions)

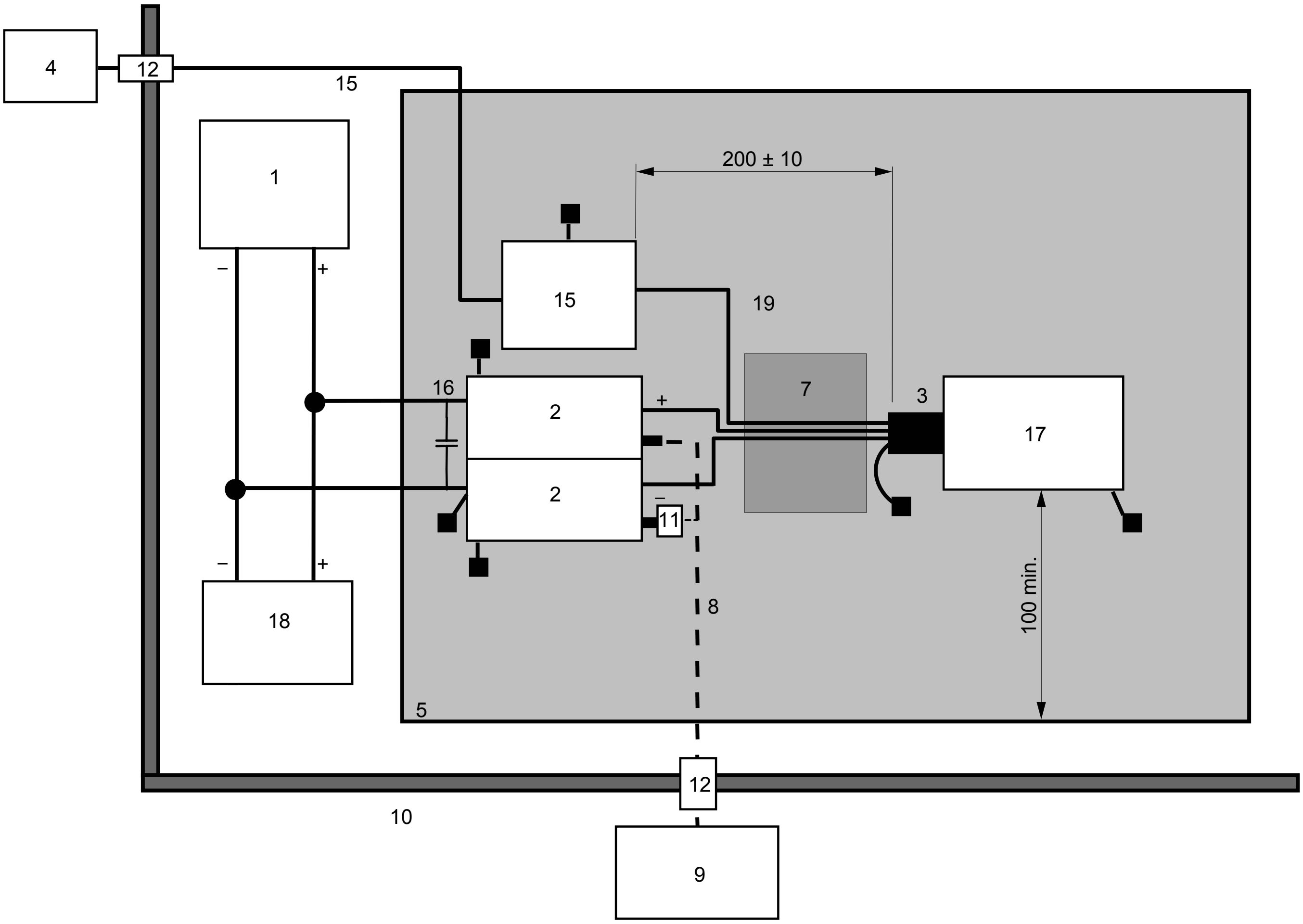
15 Non-conductive belt/coupler

16 Load resistor

NOTE The EUT housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 8 – Conducted emissions – Test layout for alternators and generators

Dimensions in millimetres – not to scale



Key

1 Power supply (may be placed on the ground plane)	11 50 Ω load
2 Artificial network	12 Bulkhead connector
3 Pencil coil	15 Optical fibre converter
4 ECU simulator (metallic casing grounded if required in test plan)	16 1 000 μF capacitor
5 Ground plane	17 Engine simulator
7 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)	18 Battery
8 High-quality coaxial cable e.g. double-shielded (50 Ω)	19 Signal line
9 Measuring instrument	
10 Shielded enclosure	

NOTE The pencil coil housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 9 – Conducted emissions – Test layout for ignition system components

6.2.3 Limits for conducted disturbances from components/modules – Voltage method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier. When using the provided limits, no correction factors for the AN shall be used.

NOTE It is recommended for acceptable radio reception in a vehicle that the conducted noise should not exceed the values shown in Tables 5 and 6, peak and average or quasi-peak and average, respectively. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined.

Table 5 – Examples of quasi-peak or peak limits for conducted disturbances – Voltage method

Service / Band	**Frequency** MHz	**Levels** in **dB**(μV)									
		Class 1		**Class 2**		**Class 3**		**Class 4**		**Class 5**	
		Peak	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**
BROADCAST											
LW	0,15 - 0,30	110	97	100	87	90	77	80	67	70	57
MW	0,53 - 1,8	86	73	78	65	70	57	62	49	54	41
SW	5,9 - 6,2	77	64	71	58	65	52	59	46	53	40
FM	76 - 108	62	49	56	43	50	37	44	31	38	25
TV Band I	41 - 88	58	-	52	-	46	-	40	-	34	-
TV Band III	174 - 230	Conducted emission – Voltage method Not applicable									
DAB III	171 - 245										
TV Band IV/V	468 - 944										
DTTV	470 - 770										
DAB L band	1447 - 1494										
SDARS	2320 - 2345										
MOBILE SERVICES											
CB	26 - 28	68	55	62	49	56	43	50	37	44	31
VHF	30 - 54	68	55	62	49	56	43	50	37	44	31
VHF	68 - 87	62	49	56	43	50	37	44	31	38	25
VHF	142 -175	Conducted emission – Voltage method Not applicable									
Analogue UHF	380 - 512										
RKE	300 - 330										
RKE	420 - 450										
Analogue UHF	820 - 960										
GSM 800	860 - 895										
EGSM/GSM 900	925 - 960										
GPS L1 civil	1567 - 1583										
GSM 1800 (PCN)	1803 - 1882										
GSM 1900	1850 - 1990										
3G / IMT 2000	1900 - 1992										
3G / IMT 2000	2010 - 2025										
3G / IMT 2000	2108 - 2172										
Bluetooth/802.11	2400 - 2500										

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user shall select the appropriate bands over which to test. When the test plan includes bands that overlap the test plan shall define the applicable limit.

Table 6 – Examples of average limits for conducted disturbances – Voltage method

Service / Band	Frequency MHz	**Levels** in **dB**(µV)				
		Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**
		AVG	**AVG**	**AVG**	**AVG**	**AVG**
BROADCAST						
LW	0,15 - 0,30	90	80	70	60	50
MW	0,53 - 1,8	66	58	50	42	34
SW	5,9 - 6,2	57	51	45	39	33
FM	76 - 108	42	36	30	24	18
TV Band I	41 - 88	48	42	36	30	24
TV Band III	174 - 230	Conducted emission – Voltage method Not applicable				
DAB III	171 - 245					
TV Band IV/V	468 - 944					
DTTV	470 - 770					
DAB L band	1447 - 1494					
SDARS	2320 - 2345					
MOBILE SERVICES						
CB	26 - 28	48	42	36	30	24
VHF	30 - 54	48	42	36	30	24
VHF	68 - 87	42	36	30	24	18
VHF	142 -175	Conducted emission – Voltage method Not applicable				
Analogue UHF	380 - 512					
RKE	300 - 330					
RKE	420 - 450					
Analogue UHF	820 - 960					
GSM 800	860 - 895					
EGSM/GSM 900	925 - 960					
GPS L1 civil	1567 - 1583					
GSM 1800 (PCN)	1803 - 1882					
GSM 1900	1850 - 1990					
3G / IMT 2000	1900 - 1992					
3G / IMT 2000	2010 - 2025					
3G / IMT 2000	2108 - 2172					
Bluetooth/802.11	2400 - 2500					

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user shall select the appropriate bands over which to test. When the test plan includes bands that overlap the test plan shall define the applicable limit.

6.3 Conducted emissions from components/modules – current probe method

6.3.1 Test set-up

6.3.1.1 Location of the EUT

The EUT shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the ground plane.

The case of the EUT shall not be grounded to the ground plane unless it is intended to simulate the actual vehicle configuration.

The EUT shall be at least 100 mm from the edge of the ground plane. The test plan shall simulate the actual vehicle configuration and shall specify: remote versus local grounding, the use of an insulating spacer, and the electrical connection of the EUT case to the ground plane.

The measuring equipment shall be as shown in Figure 10.

6.3.1.2 Location of the test harness

The test harness shall be $\left(1\,700\ {}^{+300}_{\ \ 0}\right)$ mm long (or as agreed upon in the test plan), and shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), positioned (50 ± 5) mm above the ground plane. The test harness wires shall be nominally parallel and adjacent unless otherwise defined in the test plan.

6.3.2 Test procedure

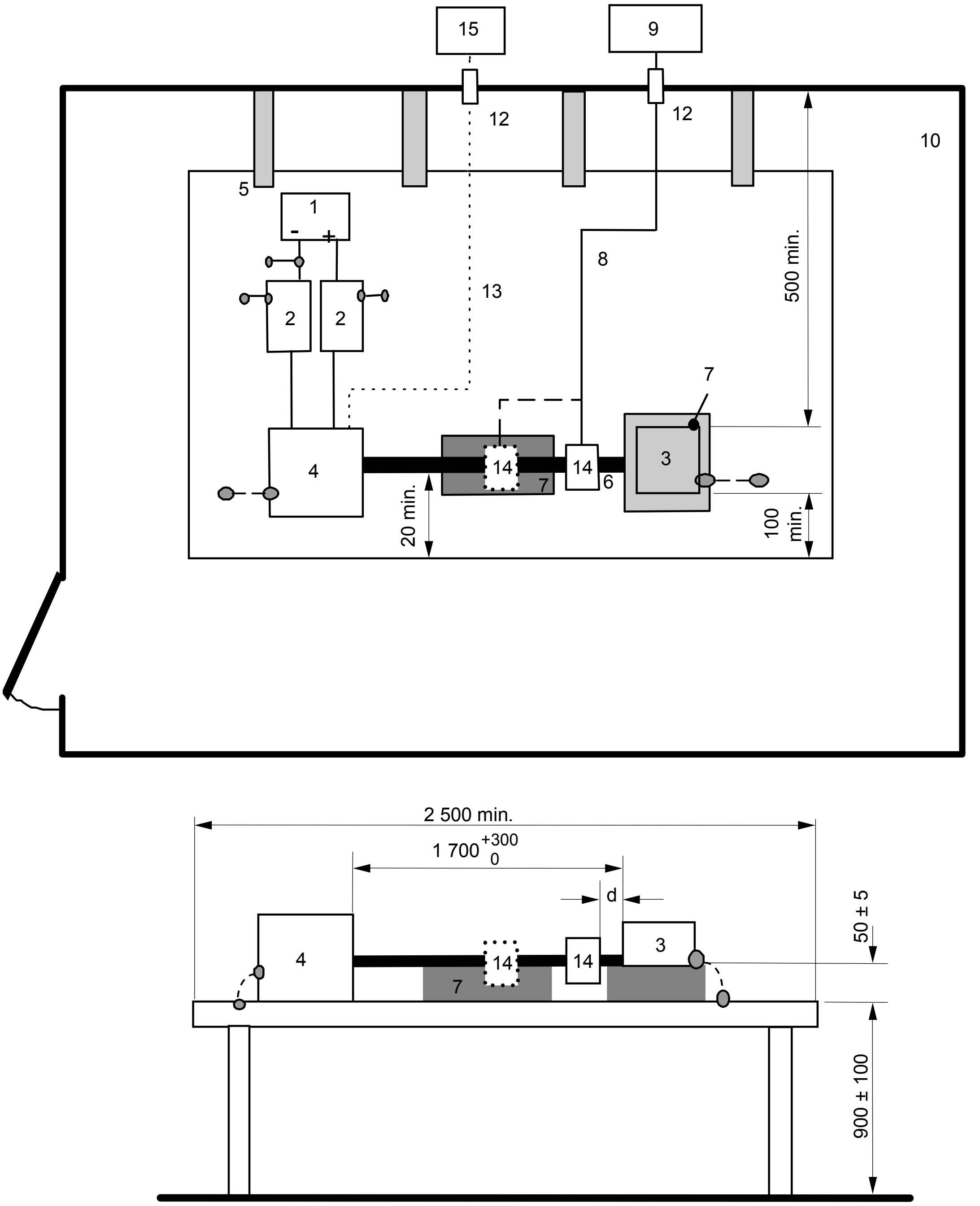
The probe (see CISPR 16-1-2) shall be mounted around the complete harness (including all wires).

Measure the emissions with the probe positioned 50 mm and 750 mm from the EUT.

In most cases, the position of maximum emission will be as close to the EUT connector as possible. Where the EUT is equipped with a metal shell connector, the probe shall be clamped to the cable immediately adjacent to the connector shell, but not around the connector shell itself. The EUT and all parts of the test set-up shall be a minimum of 100 mm from the edge of the ground plane.

NOTE Some additional measurements may be defined in the test plan with only the positive supply wire in the probe and/or only the negative supply wire in the probe. For these test configurations limits should be defined in the test plan.

Dimensions in millimetres – not to scale



Key

1	Power supply
2	Artificial network
3	EUT (connected to ground if specified in the test plan)
4	Load simulator (placement and ground connection according to ISO 11452-4)
5	Ground plane
6	Wiring harness
7	Low relative permittivity support (εr ≤ 1,4)
8	High-quality coaxial cable e.g. double-shielded (50 Ω)
9	Measuring instrument
10	Shielded enclosure
12	Bulkhead connector
13	Optical fibers
14	Current probe (represented at 2 positions)
15	Stimulation and monitoring system
d	The distance from the EUT to the closest probe position

Figure 10 – Conducted emissions – Example of test layout for current probe measurements

6.3.3 Limits for conducted disturbances from components/modules – Current probe method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

NOTE It is recommended for acceptable radio reception in a vehicle that the conducted noise should not exceed the values shown in Tables 7 and 8, peak and average or quasi-peak and average limits, respectively. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined.

Table 7 – Examples of quasi-peak and peak limits for conducted disturbances – Control/signal lines – Current probe method

Service / Band	**Frequency** MHz	**Levels** in **dB**(µA)									
		Class 1		**Class 2**		**Class 3**		**Class 4**		**Class 5**	
		Peak	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**
BROADCAST											
LW	0,15 - 0,30	90	77	80	67	70	57	60	47	50	37
MW	0,53 - 1,8	58	45	50	37	42	29	34	21	26	13
SW	5,9 - 6,2	43	30	37	24	31	18	25	12	19	6
FM	76 - 108	28	15	22	9	16	3	10	-3	4	-9
TV Band I	41 - 88	24	-	18	-	12	-	6	-	0	-
TV Band III	174 - 230	Conducted emission – control/signal lines Not applicable									
DAB III	171 - 245										
TV Band IV/V	468 - 944										
DTTV	470 - 770										
DAB L band	1447 - 1494										
SDARS	2320 - 2345										
MOBILE SERVICES											
CB	26 - 28	34	21	28	15	22	9	16	3	10	-3
VHF	30 - 54	34	21	28	15	22	9	16	3	10	-3
VHF	68 - 87	28	15	22	9	16	3	10	-3	4	-9
VHF	142 -175	Conducted emission – control/signal lines Not applicable									
Analogue UHF	380 - 512										
RKE	300 - 330										
RKE	420 - 450										
Analogue UHF	820 - 960										
GSM 800	860 - 895										
EGSM/GSM 900	925 - 960										
GPS L1 civil	1567 - 1583										
GSM 1800 (PCN)	1803 - 1882										
GSM 1900	1850 - 1990										
3G / IMT 2000	1900 - 1992										
3G / IMT 2000	2010 - 2025										
3G / IMT 2000	2108 - 2172										
Bluetooth/802.11	2400 - 2500										

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user shall select the appropriate bands over which to test. When the test plan includes bands that overlap the test plan shall define the applicable limit.

Table 8 – Examples of average limits for conducted disturbances – Control/signal lines – Current probe method

Service / Band	**Frequency** MHz	**Levels** in **dB**(µA)				
		Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**
		AVG	**AVG**	**AVG**	**AVG**	**AVG**
BROADCAST						
LW	0,15 - 0,30	70	60	50	40	30
MW	0,53 - 1,8	38	30	22	14	6
SW	5,9 - 6,2	23	17	11	5	-1
FM	76 - 108	8	2	-4	-10	-16
TV Band I	41 - 88	14	8	2	-4	-10
TV Band III	174 - 230	Conducted emission – control/signal lines Not applicable				
DAB III	171 - 245					
TV Band IV/V	468 - 944					
DTTV	470 - 770					
DAB L band	1447 - 1494					
SDARS	2320 - 2345					
MOBILE SERVICES						
CB	26 - 28	14	8	2	-4	-10
VHF	30 - 54	14	8	2	-4	-10
VHF	68 - 87	8	2	-4	-10	-16
VHF	142 -175	Conducted emission – control/signal lines Not applicable				
Analogue UHF	380 - 512					
RKE	300 - 330					
RKE	420 - 450					
Analogue UHF	820 - 960					
GSM 800	860 - 895					
EGSM/GSM 900	925 - 960					
GPS L1 civil	1567 – 1583					
GSM 1800 (PCN)	1803 - 1882					
GSM 1900	1850 - 1990					
3G	1900 - 1992					
3G	2010 - 2025					
3G	2108 - 2172					
Bluetooth/802.11	2400 - 2500					

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user shall select the appropriate bands over which to test. When the test plan includes bands that overlap the test plan shall define the applicable limit.

6.4 Radiated emissions from components/modules - ALSE method

6.4.1 General

Measurements of radiated field strength shall be made in an ALSE to eliminate the high levels of extraneous disturbance from electrical equipment and broadcasting stations.

NOTE 1 Conducted emissions will contribute to the radiated emissions measurements because of radiation from the wiring in the test set-up. Therefore, it is advisable to establish conformance with the conducted emissions requirements before performing the radiated emissions test.

NOTE 2 Disturbance to the vehicle on-board receiver can be caused by direct radiation from one or more leads in the vehicle wiring harness. This coupling mode to the vehicle receiver affects both the type of testing and the means of reducing the disturbance at the source.

NOTE 3 Vehicle components which are not effectively grounded to the vehicle by short ground leads, or which have several harness leads carrying the disturbance voltage, will have radiated emissions that do not correlate well with its conducted emissions. This has been shown to give better correlation with the complete vehicle test for components installed in this way.

Examples of component installations for which this test is applicable include, but are not limited to:

- electronic control systems containing microprocessors;
- two speed wiper motors with negative supply switching;
- suspension control systems with strut-mounted actuator motors;
- engine cooling and heater blower motors mounted in plastic or other insulated housings.

6.4.2 Test set-up

For radiated emissions measurements, the arrangement of the EUT, test harness, load simulator and measuring equipment shall be equivalent to the examples shown in Figures 12 to 15.

6.4.2.1 Antenna systems

Measurements shall be made using linearly polarised electric field antennas that have a nominal 50 Ω output impedance.

NOTE 1 To improve consistency of results between laboratories, the following antennas are recommended:

a)	0,15 MHz to 30 MHz	1 m vertical monopole (where this is not 50 Ω, a suitable **antenna matching unit** must be used);
b)	30 MHz to 300 MHz	a biconical antenna;
c)	200 MHz to 1 000 MHz	a log-periodic antenna;
d)	1 000 MHz to 2 500 MHz	a horn or log-periodic antenna.

The method to be used for characterization of the vertical monopole (rod) antenna is given in CISPR 16-1-4.

NOTE 2 Use the 1 m method in SAE ARP 958.1 Rev D February 2003 for determining biconical, log-periodic and horn antenna factors.

NOTE 3 Biconical antennas usually have a SWR of up to 10:1 in the frequency range of 30 MHz to 80 MHz. Therefore an additional measurement error may occur when the receiver input impedance differs from 50 Ω. The use of an attenuator (3 dB minimum) at the receiver's input or the input of an additional preamplifier (if possible) will keep this additional error low.

6.4.2.2 Antenna matching unit for monopole antenna

Correct impedance matching between the antenna and the measuring instrument of 50 Ω shall be maintained in the frequency ranges selected for the test. There shall be a maximum SWR of 2:1 at the output port of the matching unit. Appropriate correction shall be made for any attenuation/gain of the antenna system from the antenna to the receiver.

NOTE Care should be taken to ensure that input voltages do not exceed the pulse input rating of the unit or overloading may occur. This is particularly important when active matching units are used.

6.4.2.3 Location of the EUT

The EUT shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the ground plane.

The case of the EUT shall not be grounded to the ground plane unless it is intended to simulate the actual vehicle configuration.

The side of the EUT, which is nearest to the front edge of the ground plane, shall be located at a distance of (200 ± 10) mm from the front edge of the ground plane.

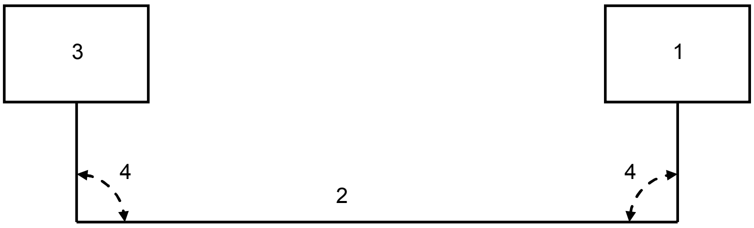
6.4.2.4 Test harness and location

The total length of the test harness between the EUT and the load simulator (or the **RF boundary**) shall not exceed 2 000 mm (or as defined in the test plan). The wiring type is defined by the actual system application and requirement.

The test harness shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the ground plane.

The length of test harness parallel to the front of the ground plane shall be (1 500 ± 75) mm.

The long segment of test harness shall be located parallel to the edge of the ground plane facing the antenna at a distance of (100 ± 10) mm from the edge. Location of the EUT and load simulator requires that the harness bend angle shall be $\left(90\ ^{+45}_{\ 0}\right)$ degrees as shown in Figure 11.



Key

1 EUT

2 Test harness

3 Load simulator

4 Angle $\left(90\ ^{+45}_{\ 0}\right)$ degrees

Figure 11 – Test harness bending requirements

6.4.2.5 Location of the load simulator

Preferably, the load simulator shall be placed directly on the ground plane. If the load simulator has a metallic case, this case shall be bonded to the ground plane.

Alternatively, the load simulator may be located adjacent to the ground plane (with the case of the load simulator bonded to the ground plane) or outside of the test chamber, provided the test harness from the EUT passes through an **RF boundary** bonded to the ground plane.

When the load simulator is located on the ground plane, the d.c. power supply lines of the load simulator shall be connected through the AN(s).

6.4.2.6 Location of the measuring antenna

The phase centre of the measuring antenna shall be (100 ± 10) mm above the ground plane for the biconical, log-periodic and horn antennas.

The height of the counterpoise of the rod antenna shall be (+10 / –20) mm relative to the ground plane and shall be bonded to the ground plane.

For radiated emissions tests, the shielded enclosure shall be of sufficient size to ensure that neither the EUT nor the test antenna shall be closer than 1 m from the walls or ceiling, or to the nearest surface of the absorber material used thereon. No part of any antenna radiating element shall be closer than 250 mm to the floor.

The distance between the longitudinal part (1 500 mm length) of the wiring harness and the reference point of the antenna shall be (1 000 ± 10) mm.

The reference point of the antenna is defined as:

- the vertical monopole element for rod antennas,
- the phase centre (mid-point) for biconical antennas,
- the tip for antennas with log-periodic elements (including biconilog antennas),
- the front aperture for horn antennas.

Each antenna (excluding the rod antenna) shall be calibrated for this reference point for a 1 000 mm measuring distance.

NOTE 1 The rod antenna is excluded because calibration is achieved by using the method defined in CISPR 16-1-4.

The phase centre of the antenna shall be in line with the centre of the longitudinal part of the wiring harness for frequencies up to 1 000 MHz.

The phase center of the antenna for frequencies above 1 000 MHz shall be in line with the EUT.

NOTE 2 The users of this standard should be aware that antenna manufacturers may give:

- Independent antenna factors for horizontal and vertical polarisations: in this case the appropriate antenna factor should be used for measurement in each polarisation.
- A single antenna factor: in this case this antenna factor should be used for measurements in both polarisations.

6.4.3 Test procedure

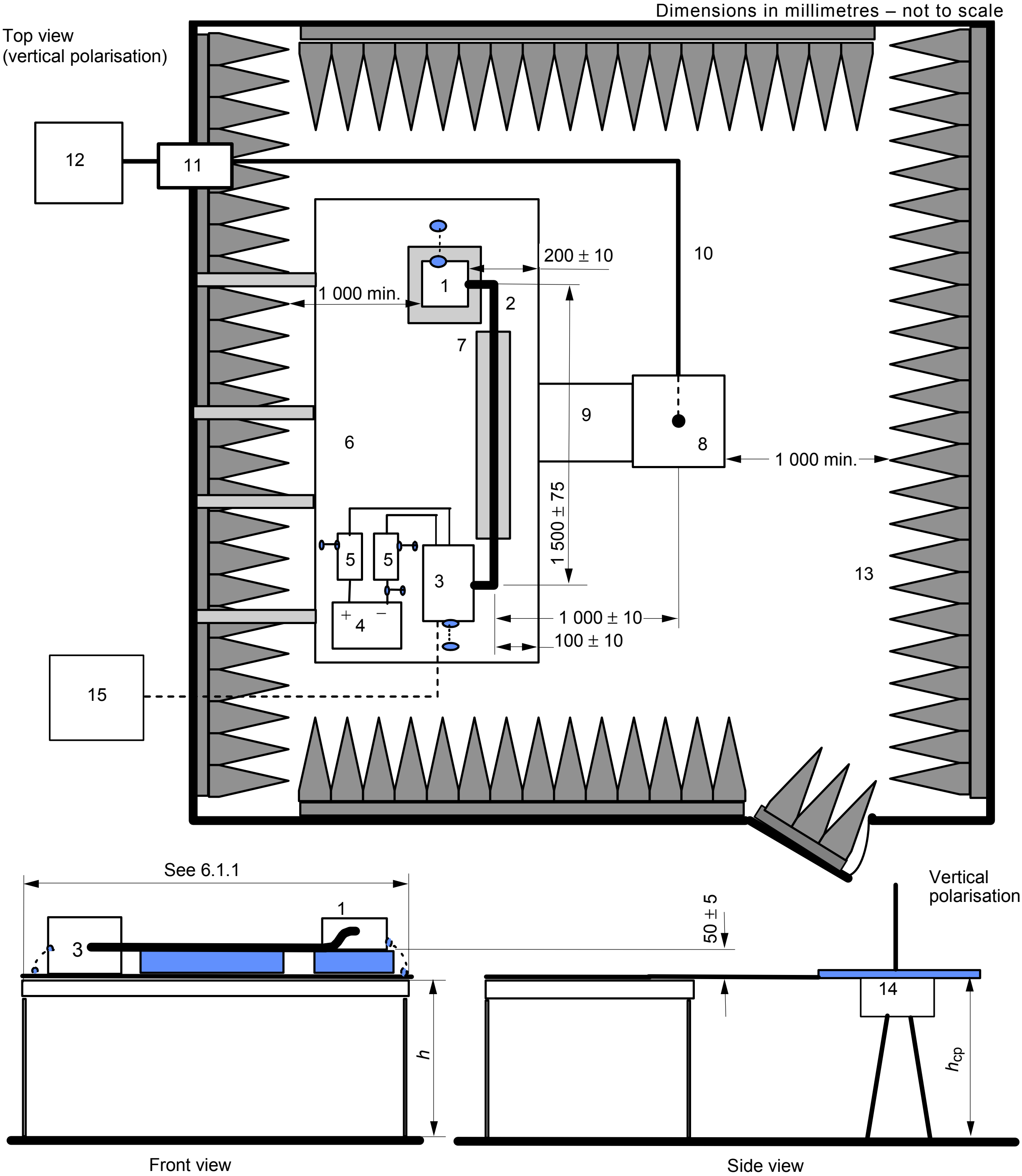
The general arrangement of the disturbance source and connecting harnesses, etc. represents a standardised test condition. Any deviations from the standard test harness length, etc. shall be agreed upon prior to testing and recorded in the test report.

The EUT shall be made to operate under typical loading and other conditions as in the vehicle such that the maximum emission state occurs. These operating conditions shall be clearly defined in the test plan to ensure supplier and customer can perform identical tests. The orientation(s) of the EUT for radiated emission measurements shall be defined in the test plan.

From 150 kHz to 30 MHz measurements shall be performed in vertical polarisation only.

From 30 MHz to 2 500 MHz measurements shall be performed in vertical and horizontal polarisations.

For radiated emission measurements, the arrangement of the EUT and measuring equipment shall be functionally equivalent to the examples shown in Figures 12 to 15.

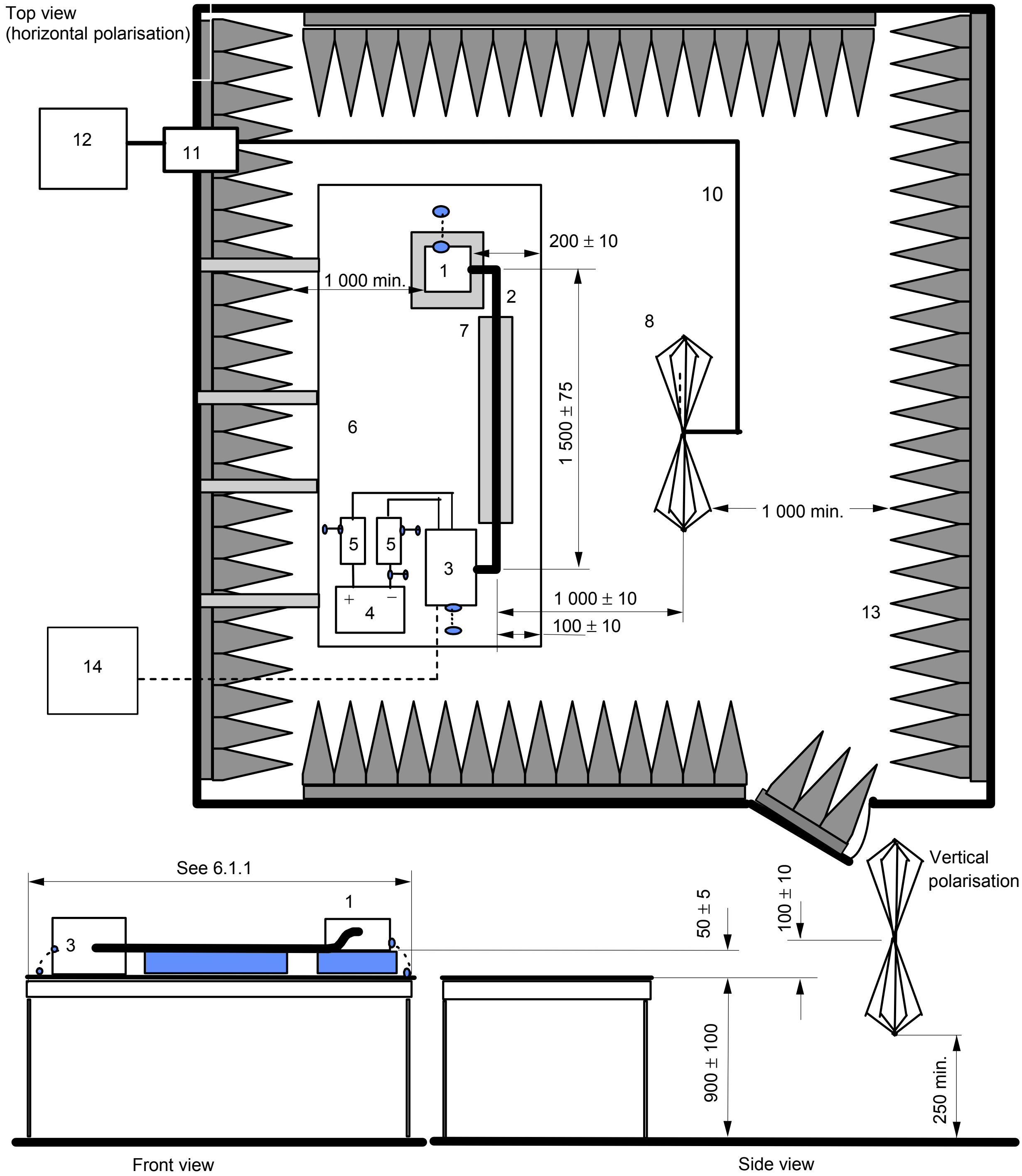


Key

1 EUT (grounded locally if required in test plan)
2 Test harness
3 Load simulator (placement and ground connection according to 6.4.2.5)
4 Power supply (location optional)
5 Artificial network (AN)
6 Ground plane (bonded to shielded enclosure)
7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)
8 Rod antenna with counterpoise (dimensions: 600 mm by 600 mm typical)
h = (900 ± 100) mm
$h_{cp} = h + (+10 / -20)$ mm
9 Grounding connection (full width bond between counterpoise and ground plane)
10 High-quality coaxial cable e.g. double-shielded (50 Ω)
11 Bulkhead connector
12 Measuring instrument
13 RF absorber material
14 Antenna matching unit (the preferred location is below the counterpoise; if above the counterpoise then the base of the antenna rod shall be at the height of the ground plane)
15 Stimulation and monitoring system

Figure 12 – Example of test set-up – rod antenna

Dimensions in millimetres – not to scale



Key

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.4.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Ground plane (bonded to shielded enclosure)

7 Low relative permittivity support (ε_r ≤ 1,4)

8 Biconical antenna

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

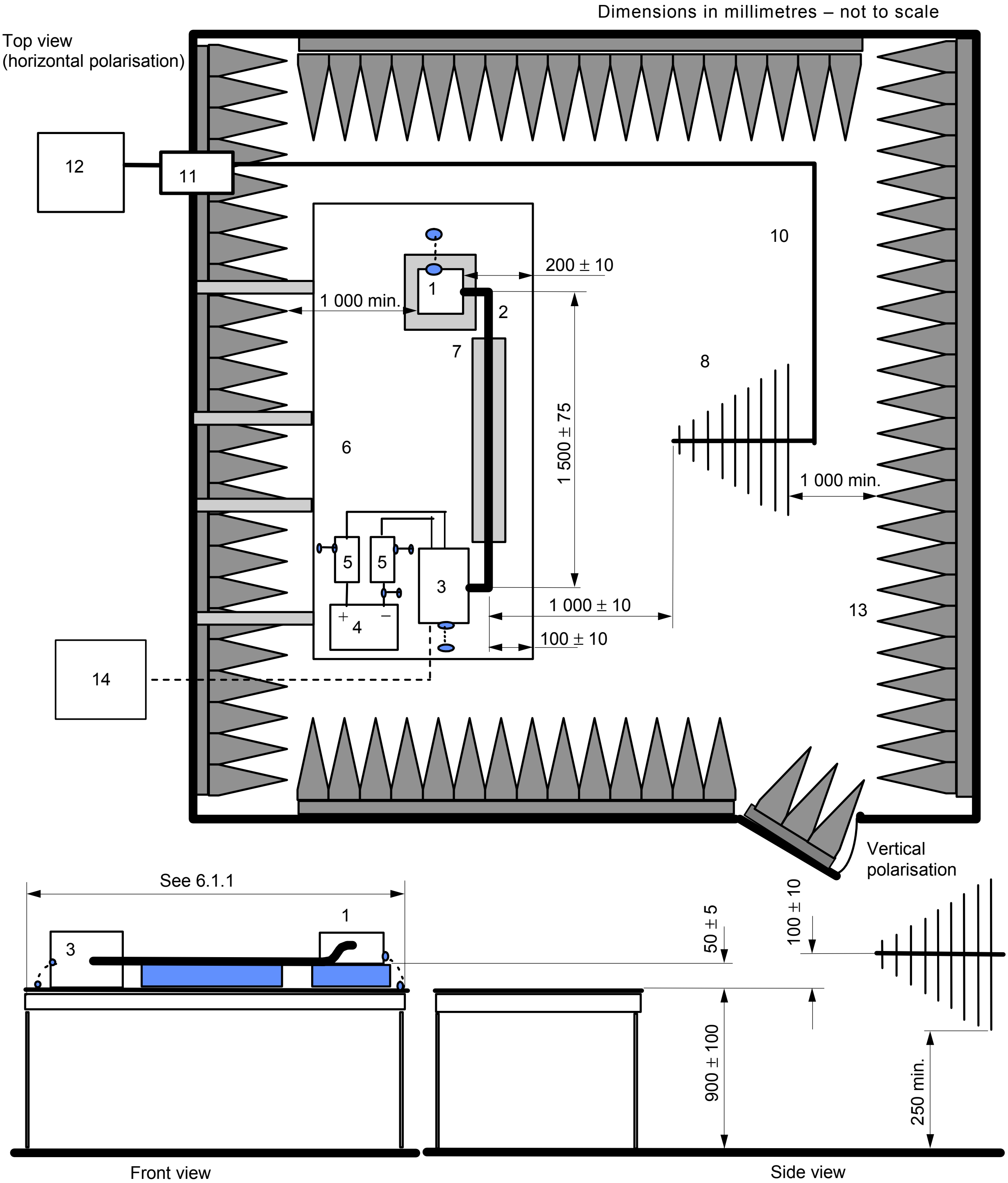
11 Bulkhead connector

12 Measuring instrument

13 RF absorber material

14 Stimulation and monitoring system

Figure 13 – Example of test set-up – biconical antenna



Key

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.4.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Ground plane (bonded to shielded enclosure)

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 Log-periodic antenna

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

11 Bulkhead connector

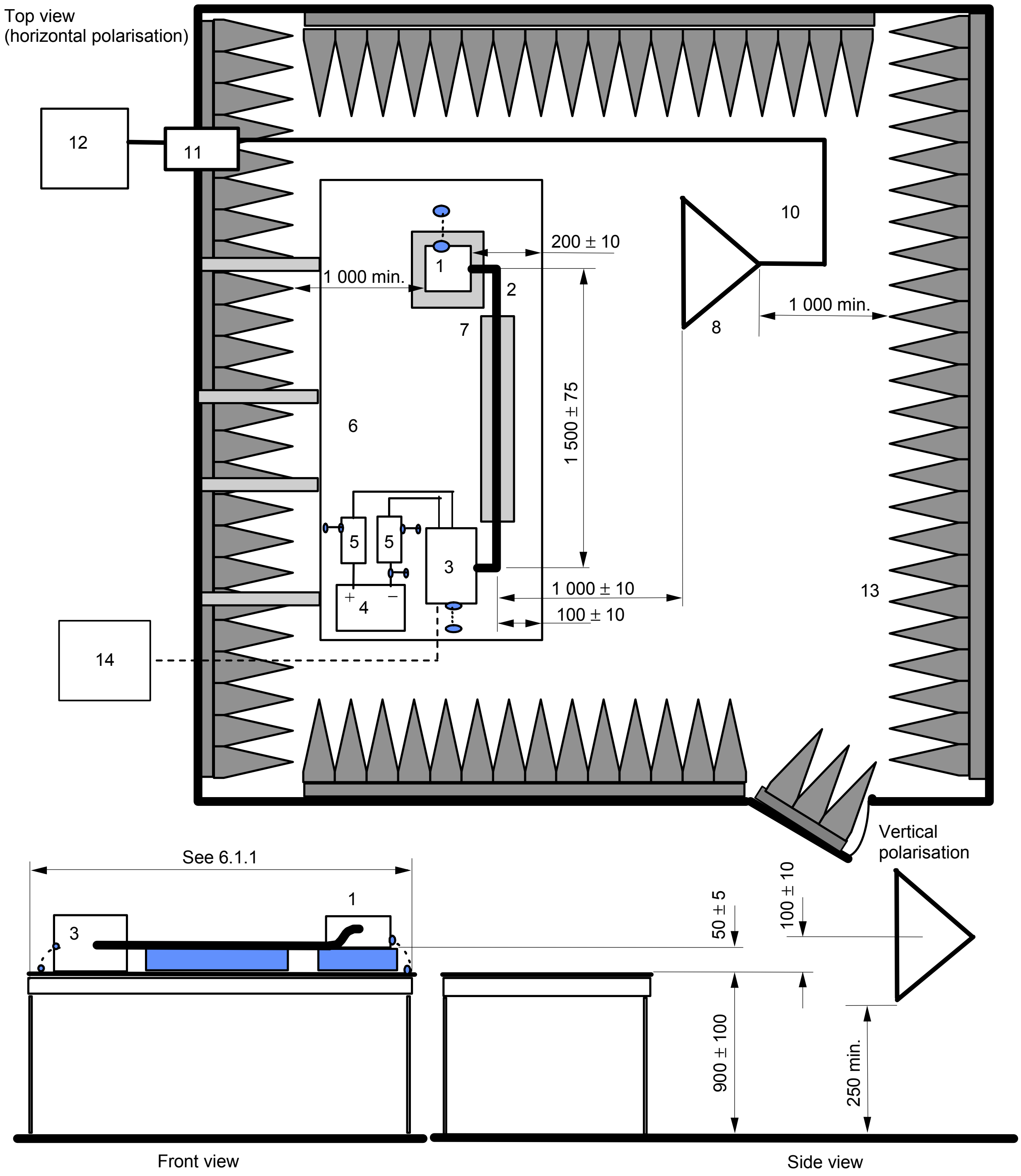
12 Measuring instrument

13 RF absorber material

14 Stimulation and monitoring system

Figure 14 – Example of test set-up – log-periodic antenna

Dimensions in millimetres – not to scale



Key

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.4.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Ground plane (bonded to shielded enclosure)

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 Horn antenna

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

11 Bulkhead connector

12 Measuring instrument

13 RF absorber material

14 Stimulation and monitoring system

Figure 15 – Example of test set-up – above 1 GHz

6.4.4 Limits for radiated disturbances from components/modules – ALSE method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

NOTE It is recommended for acceptable radio reception in a vehicle that the radiated noise should not exceed the values shown in Tables 9 and 10, peak and average or quasi-peak and average limits, respectively. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined. For the GPS band a specific limit characteristic is recommended. This is shown in Figure 16.

Table 9 – Examples of quasi-peak or peak limits for radiated disturbances – ALSE

Service / Band	**Frequency** MHz	**Levels** in **dB**(µV/m)									
		Class 1		**Class 2**		**Class 3**		**Class 4**		**Class 5**	
		Peak	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**
BROADCAST											
LW	0,15 - 0,30	86	73	76	63	66	53	56	43	46	33
MW	0,53 - 1,8	72	59	64	51	56	43	48	35	40	27
SW	5,9 - 6,2	64	51	58	45	52	39	46	33	40	27
FM	76 - 108	62	49	56	43	50	37	44	31	38	25
TV Band I	41 - 88	52	-	46	-	40	-	34	-	28	-
TV Band III	174 - 230	56	-	50	-	44	-	38	-	32	-
DAB III	171 - 245	50	-	44	-	38	-	32	-	26	-
TV Band IV/	468 - 944	65	-	59	-	53	-	47	-	41	-
DTTV	470 - 770	69	-	63	-	57	-	51	-	45	-
DAB L band	1447 - 1494	52	-	46	-	40	-	34	-	28	-
SDARS	2320 - 2345	58	-	52	-	46	-	40	-	34	-
MOBILE SERVICES											
CB	26 - 28	64	51	58	45	52	39	46	33	40	27
VHF	30 - 54	64	51	58	45	52	39	46	33	40	27
VHF	68 - 87	59	46	53	40	47	34	41	28	35	22
VHF	142 -175	59	46	53	40	47	34	41	28	35	22
Analogue UHF	380 - 512	62	49	56	43	50	37	44	31	38	25
RKE	300 - 330	56	-	50	-	44	-	38	-	32	-
RKE	420 - 450	56	-	50	-	44	-	38	-	32	-
Analogue UHF	820 - 960	68	55	62	49	56	43	50	37	44	31
GSM 800	860 - 895	68	-	62	-	56	-	50	-	44	-
EGSM/GSM 900	925 - 960	68	-	62	-	56	-	50	-	44	-
GPS L1 civil	1567 - 1583	-	-	-	-	-	-	-	-	-	-
GSM 1800 (PCN)	1803 - 1882	68	-	62	-	56	-	50	-	44	-
GSM 1900	1850 - 1990	68	-	62	-	56	-	50	-	44	-
3G / IMT 2000	1900 - 1992	68	-	62	-	56	-	50	-	44	-
3G / IMT 2000	2010 - 2025	68	-	62	-	56	-	50	-	44	-
3G / IMT 2000	2108 - 2172	68	-	62	-	56	-	50	-	44	-
Bluetooth/802.11	2400 - 2500	68	-	62	-	56	-	50	-	44	-

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user shall select the appropriate bands over which to test. When the test plan includes bands that overlap the test plan shall define the applicable limit.

Table 10 – Examples of average limits for radiated disturbances – ALSE

Service / Band	**Frequency** MHz	**Levels** in **dB**(µV/m)				
		Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**
		AVG	**AVG**	**AVG**	**AVG**	**AVG**
BROADCAST						
LW	0,15 - 0,30	66	56	46	36	26
MW	0,53 - 1,8	52	44	36	28	20
SW	5,9 - 6,2	44	38	32	26	20
FM	76 - 108	42	36	30	24	18
TV Band I	41 - 88	42	36	30	24	18
TV Band III	174 - 230	46	40	34	28	22
DAB III	171 - 245	40	34	28	22	16
TV Band IV/V	468 - 944	55	49	43	37	31
DTTV	470 - 770	59	53	47	41	35
DAB L band	1447 - 1494	42	36	30	24	18
SDARS	2320 - 2345	48	42	36	30	24
MOBILE SERVICES						
CB	26 - 28	44	38	32	26	20
VHF	30 - 54	44	38	32	26	20
VHF	68 - 87	39	33	27	21	15
VHF	142 -175	39	33	27	21	15
Analogue UHF	380 - 512	42	36	30	24	18
RKE	300 - 330	42	36	30	24	18
RKE	420 - 450	42	36	30	24	18
Analogue UHF	820 - 960	48	42	36	30	24
GSM 800	860 - 895	48	42	36	30	24
EGSM/GSM 900	925 - 960	48	42	36	30	24
GPS L1 civil	1567 - 1583	34	28	22	16	10
GSM 1800 (PCN)	1803 - 1882	48	42	36	30	24
GSM 1900	1850 - 1990	48	42	36	30	24
3G / IMT 2000	1900 - 1992	48	42	36	30	24
3G / IMT 2000	2010 - 2025	48	42	36	30	24
3G / IMT 2000	2108 - 2172	48	42	36	30	24
Bluetooth/802.11	2400 - 2500	48	42	36	30	24

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user shall select the appropriate bands over which to test. When the test plan includes bands that overlap the test plan shall define the applicable limit.

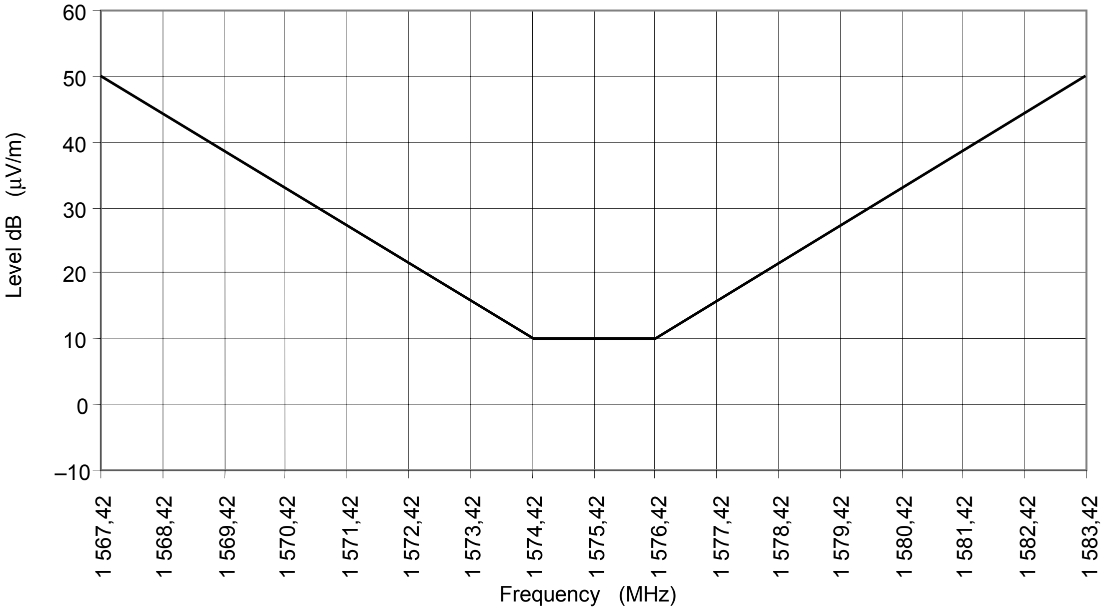
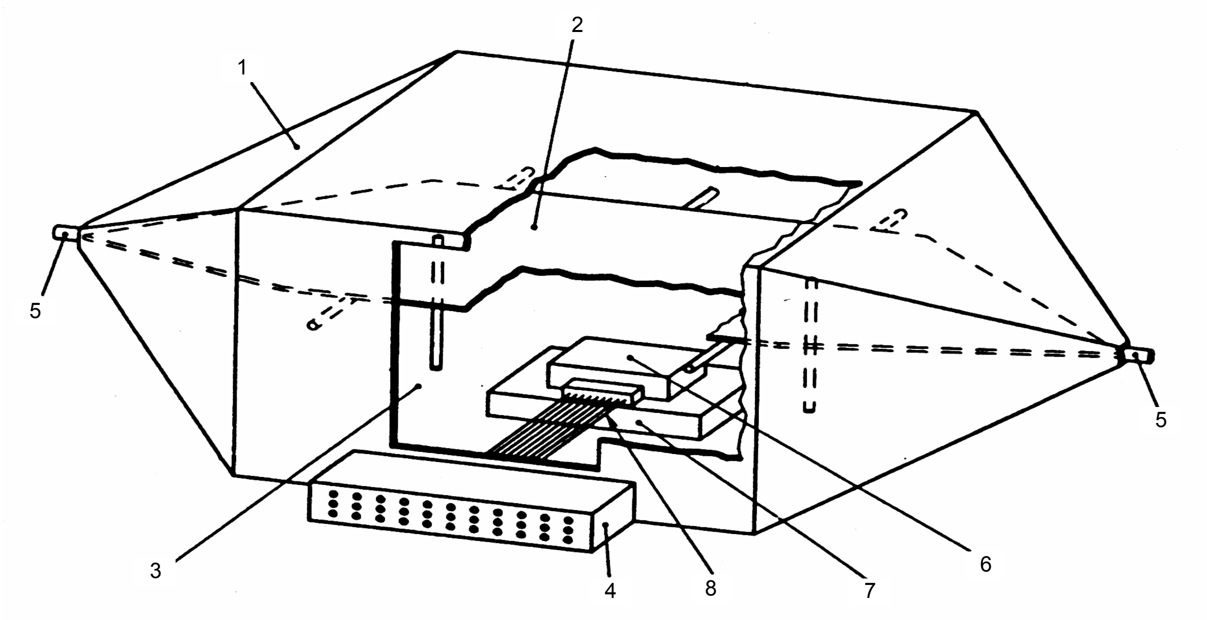


Figure 16 – Example of average limit for radiated disturbances from components GPS band 1 567,42 to 1 583,42 MHz – Class 5

6.5 Radiated emissions from components/modules – TEM cell method

6.5.1 General

Measurements of radiated field strength shall be made in a shielded enclosure to eliminate the high levels of extraneous disturbance from electrical equipment and radiated fields from nearby broadcast and other radio transmitters. The TEM cell works as a shielded enclosure. An example of a TEM cell is shown in Figure 17. Information relating to the size and construction of a TEM cell for component measurement is given in Annex F.



Key

1	Outer shield
2	Septum (inner conductor)
3	Access door
4	Connector panel (optional)
5	Coaxial connectors
6	EUT
7	Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)
8	Artificial harness

NOTE The connectors on the connector panel should be coaxial RF connectors if the RF boundary extends outside of the TEM cell.

Figure 17 – TEM cell (example)

The upper frequency limit of this test method is a direct function of the TEM cell dimensions, the dimensions of the components/module (arrangement included), and the RF filter characteristic. Measurements shall not be made near the TEM cell resonance frequencies.

A TEM cell is recommended for testing automotive electronic systems in the frequency range from 150 kHz to 200 MHz. The TEM cells boxed in Annex F, Table F.1, are typical of those used in automotive work.

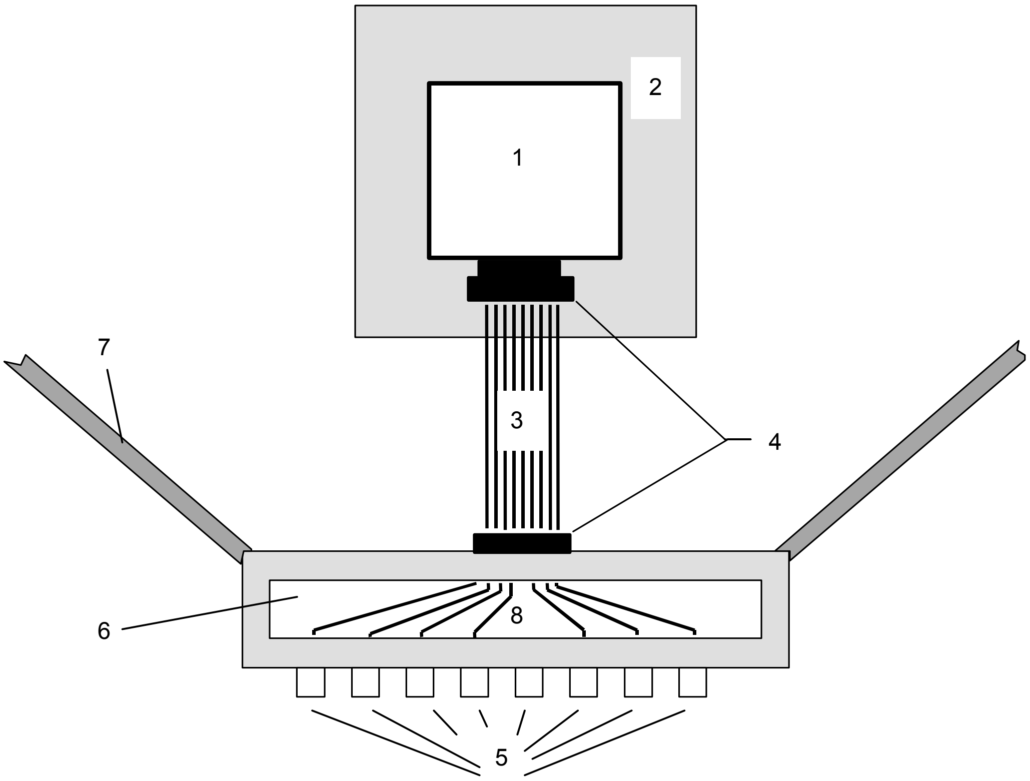
In order to achieve reproducible test results the EUT and the test harness shall be placed in the TEM cell in the same position for each repeated measurement.

For the purpose of this test, the septum of the TEM cell functions in a similar way to a receiving antenna.

6.5.2 Test set-up

6.5.2.1 Set-up with major field coupling to the wiring harness

The TEM cell shall have a connector panel connected as close as possible to a plug connector (see Figures 18 and 19).

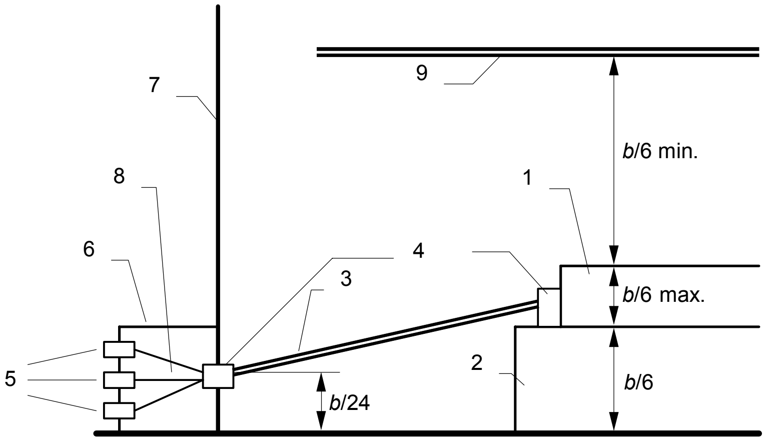


Key

1 EUT
2 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)
3 Printed circuit board or wiring harness
4 Connector
5 Coaxial connectors
6 Connector panel (optional)
7 TEM cell wall
8 RF coaxial cables

NOTE All leads to the EUT shall pass through an RF boundary. The RF boundary is either at the wall of the TEM cell or extended through RF coaxial cable (8) and coaxial connectors (5). The boundary is terminated by RF-filters which can be connected inside the connector panel (6) or directly outside to the coaxial connectors (5). The cables in the connector panel should be coaxial if the RF-filters are connected to the coaxial connectors (5).

Figure 18 – Example of arrangement of leads in the TEM cell and to the connector panel



Key

1 EUT

2 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

3 Printed circuit board (no ground plane) or wiring harness, not shielded

4 Connector

5 Coaxial connectors

6 Connector panel (optional)

7 TEM cell wall

8 Cables

9 Septum

b is the TEM cell height (see Annex F)

NOTE The connectors on the connector panel should be coaxial RF connectors if the RF boundary extends outside of the TEM cell.

Figure 19 – Example of the arrangement of the connectors, the lead frame and the dielectric support

All supply and signal leads from the EUT are directly connected to the artificial harness (e.g. a lead frame). The plugs at the connector panel which are not required shall be sealed so that they are RF-tight.

The connection of the positive power lead shall be through the AN (see 6.1.2), direct at the connector panel.

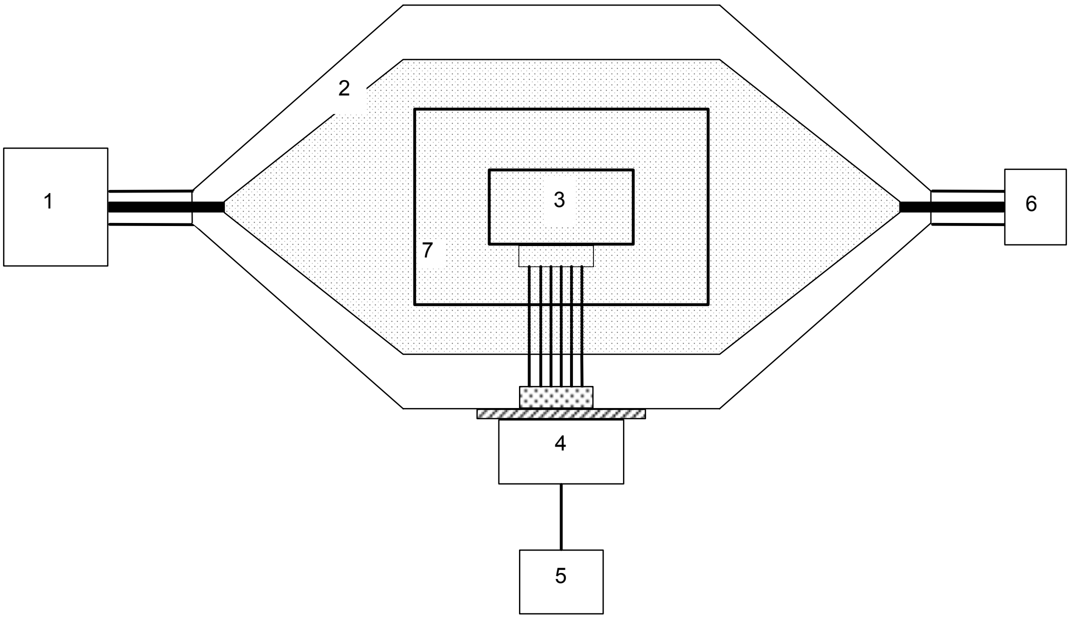
It is not permitted to ground the EUT directly to the TEM cell floor. The grounding shall be done at the connector panel.

6.5.2.2 Set-up with major field coupling to the EUT

The test set-up is similar to the method shown above, except that the leads to the EUT are positioned and shielded to minimise electromagnetic radiation from the leads. This is accomplished by positioning the leads flat across the bottom of the TEM cell and bringing them vertically to the EUT. The use of a sealed battery and shielded wiring in the TEM cell will further reduce the electromagnetic radiation from power and signal leads. To minimise the radiation from the wiring further, shielding foil tape can be applied over the leads.

6.5.3 Test procedure

An example of the TEM cell method test layout is given in Figure 20. The general arrangement of the EUT, the harness, the filter system at the TEM cell's wall, etc., represent a standardised test condition. Any deviations from the standard test configuration shall be agreed upon prior to testing and recorded in the test report.



Key

1 Measuring instrument

2 TEM cell

3 EUT

4 AN (see 6.1.2)

5 Power supply

6 50 Ω termination resistor

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

Figure 20 – Example of the TEM cell method test layout

The EUT shall be supported *b*/6 (see Figure 19) above the TEM cell floor by non-conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$) in the allowed working region. The length of the artificial harness (e.g. a lead frame) shall be 450 +/– 45 mm and positioned as shown in Figures 18 and 19.

The wiring arrangement of the artificial harness, the design and the overall height of the EUT's connector constitute electrical coupling loops and dipoles which have influence on the test results. All connections between the plug and contacts of the EUT's (multipole) connector and the artificial harness shall be as short as possible. Repeat measurements shall be performed using the same arrangement of the artificial harness, the same overall height of the EUT's connector and the same pin assignment on both connectors. Care shall be taken, if the size of the EUT and the allowed working region is nearly the same. In such a case, special care should be taken to define and document the test layout in the test plan.

The EUT shall be installed to operate under typical loading and other conditions in the vehicle in such a way that the maximum emission state occurs. These operating conditions must be defined in the test plan to ensure supplier and customer can perform identical tests.

NOTE Different orthogonal orientations of the EUT could lead to different levels of measured electromagnetic energy.

The positive supply line shall have an RF filter at the TEM cell input. The artificial network (AN) of 6.1.2 shall be used as this filter. The AN shall be connected directly to the TEM cell and shall be screened, so that the negative supply line is grounded at the connector panel. The RF sampling port of the AN shall be terminated with a 50 Ω load.

All sensor and actuator leads of the EUT shall be connected to a peripheral interface, which simulates the operation in the vehicle.

To minimise influences of the wiring outside the TEM cell, low pass filters shall be used, which shall be connected directly to the BNC panel. The performance of the filters depends on the frequency range of the EUT's wanted signals. If no other configuration is specified in the test plan the filters shall perform like the artificial network with a 50 Ω impedance as described in Annex E.

To eliminate influences of its length and arrangement the wiring inside the connector panel shall be as short as possible via 50 Ω coaxial cables if a BNC connector panel is used. The shielding (outer conductor) of the cables shall be grounded at both ends.

Repeat measurements shall be performed using the same RF port of the TEM cell, with the opposite port terminated by a 50 Ω impedance.

6.5.4 Limits for radiated disturbances from components/modules – TEM cell method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

NOTE Recommended limits for radiated disturbances from components (both the set-up with major field coupling to the wiring harness (6.5.2.1) and the set-up with major coupling to the EUT (6.5.2.2)) are given in Tables 11 and 12. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined.

Table 11 – Examples of quasi-peak or peak limits for radiated disturbances – TEM cell

Service / Band	Frequency MHz	Levels in dB(µV)									
		Class 1		Class 2		Class 3		Class 4		Class 5	
		Peak	Quasi-peak	Peak	Quasi-peak	Peak	Quasi-peak	Peak	Quasi-peak	Peak	Quasi-peak
BROADCAST											
LW	0,15 - 0,30	66	53	56	43	46	33	36	23	26	13
MW	0,53 - 1,8	52	39	44	31	36	23	28	15	20	7
SW	5,9 - 6,2	44	31	38	25	32	19	26	13	20	7
FM	76 - 108	50	37	44	31	38	25	32	19	26	13
TV Band I	41 - 88	40	-	34	-	28	-	22	-	16	-
TV Band III	174 - 230	40	-	34	-	28	-	22	-	16	-
DAB III	171 - 245	34	-	28	-	22	-	16	-	10	-
TV Band IV/V	468 - 944	Radiated emission – TEM cell Not applicable									
DTTV	470 - 770										
DAB L band	1447 - 1494										
SDARS	2320 - 2345										
MOBILE SERVICES											
CB	26 - 28	44	31	38	25	32	19	26	13	20	7
VHF	30 - 54	44	31	38	25	32	19	26	13	20	7
VHF	68 - 87	44	31	38	25	32	19	26	13	20	7
VHF	142 -175	44	31	38	25	32	19	26	13	20	7
Analogue UHF	380 - 512	Radiated emission – TEM cell Not applicable									
RKE	300 - 330										
RKE	420 - 450										
Analogue UHF	820 - 960										
GSM 800	860 - 895										
EGSM/GSM 900	925 - 960										
GPS L1 civil	1567 - 1583										
GSM 1800 (PCN)	1803 - 1882										
GSM 1900	1850 - 1990										
3G / IMT 2000	1900 - 1992										
3G / IMT 2000	2010 - 2025										
3G / IMT 2000	2108 - 2172										
Bluetooth/802.11	2400 - 2500										

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user shall select the appropriate bands over which to test. When the test plan includes bands that overlap the test plan shall define the applicable limit.

Table 12 – Examples of average limits for radiated disturbances – TEM cell

Service / Band	**Frequency** MHz	**Levels** in **dB**(µV)				
		Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**
		AVG	**AVG**	**AVG**	**AVG**	**AVG**
BROADCAST						
LW	0,15 - 0,30	46	36	26	16	6
MW	0,53 - 1,8	32	24	16	8	0
SW	5,9 - 6,2	24	18	12	6	0
FM	76 - 108	30	24	18	12	6
TV Band I	41 - 88	30	24	18	12	6
TV Band III	174 - 230	30	24	18	12	6
DAB III	171 - 245	24	18	12	6	0
TV Band IV/V	468 - 944	Radiated emission – TEM cell Not applicable				
DTTV	470 - 770					
DAB L band	1447 - 1494					
SDARS	2320 - 2345					
MOBILE SERVICES						
CB	26 - 28	24	18	12	6	0
VHF	30 - 54	24	18	12	6	0
VHF	68 - 87	24	18	12	6	0
VHF	142 -175	24	18	12	6	0
Analogue UHF	380 - 512	Radiated emission – TEM cell Not applicable				
RKE	300 - 330					
RKE	420 - 450					
Analogue UHF	820 - 960					
GSM 800	860 - 895					
EGSM/GSM 900	925 - 960					
GPS L1 civil	1567 - 1583					
GSM 1800 (PCN)	1803 - 1882					
GSM 1900	1850 - 1990					
3G / IMT 2000	1900 - 1992					
3G / IMT 2000	2010 - 2025					
3G / IMT 2000	2108 - 2172					
Bluetooth/802.11	2400 - 2500					

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

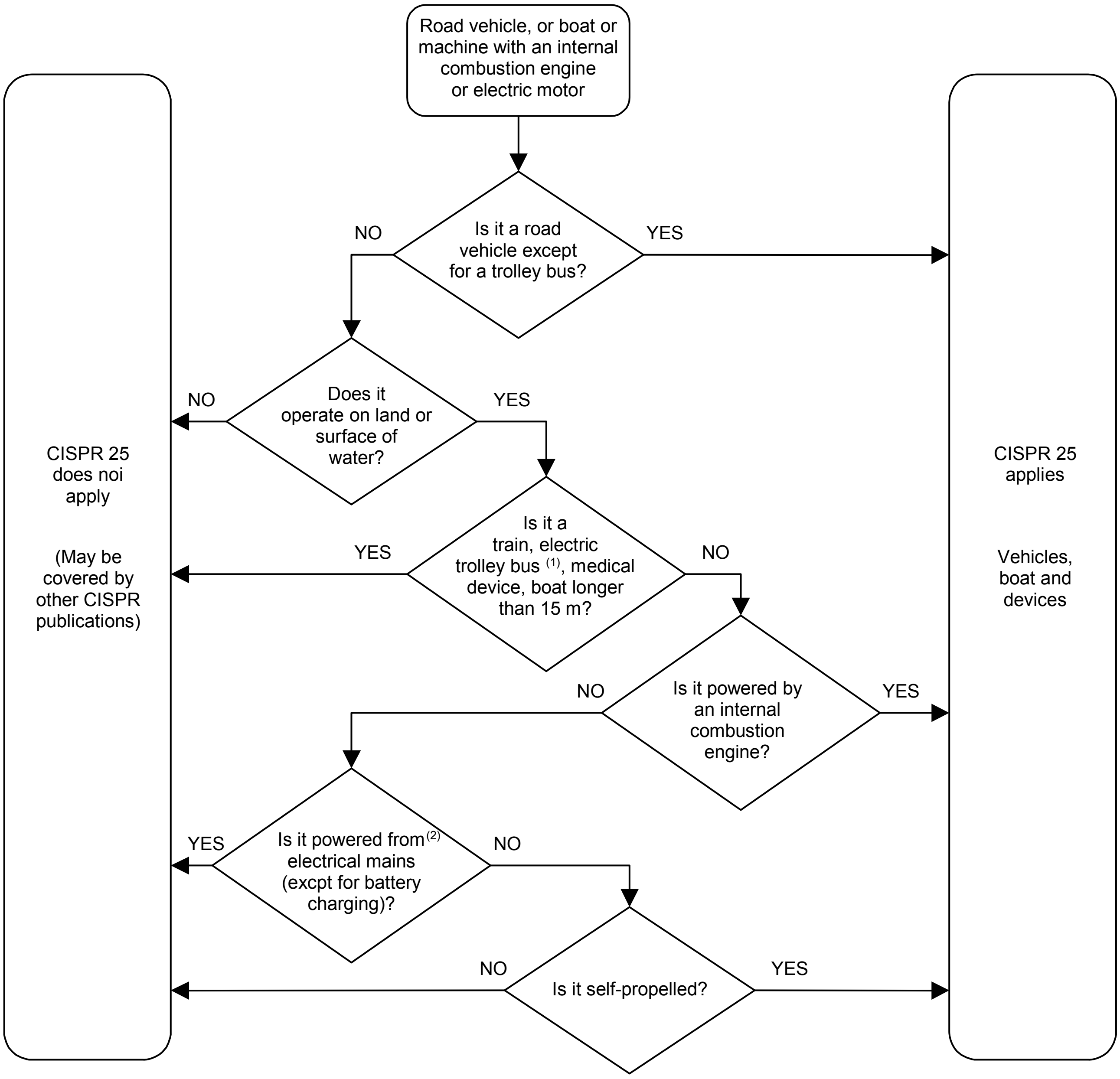
NOTE 2 Where multiple bands use the same limits the user shall select the appropriate bands over which to test. When the test plan includes bands that overlap the test plan shall define the applicable limit.

6.6 Radiated emissions from components/modules – Stripline method

Refer to Annex G.

Annex A
(informative)

Flow chart for checking the applicability of CISPR 25


Road vehicle, or boat or machine with an internal combustion engine or electric motor
Is it a road vehicle except for a trolley bus?
NO
YES
Does it operate on land or surface of water?
NO
YES
Is it a train, electric trolley bus (1), medical device, boat longer than 15 m?
YES
NO
Is it powered by an internal combustion engine?
NO
YES
Is it powered from(2) electrical mains (excpt for battery charging)?
YES
NO
Is it self-propelled?
NO
YES
CISPR 25 does noi apply
(May be covered by other CISPR publications)
CISPR 25 applies
Vehicles, boat and devices

(1) In the case of a dual-mode trolley bus (e.g. propelled by power from either a.c./d.c. mains or an internal combustion engine), the a.c./d.c. mains portion of the vehicle propulsion system shall be excluded from this standard.

(2) Connection to the electrical mains is the work of another CISPR subcommittee.

This chart is intended to assist with determining whether a particular product is covered by this publication. In case of conflict between this chart and Clause 1, Scope, Clause 1 shall take precedence.

Annex B
(normative)

Antenna matching unit – Vehicle test

B.1 Antenna matching unit parameters (150 kHz to 6,2 MHz)

The requirements for the measurement equipment are defined in 5.1.2.1.

B.2 Antenna matching unit – verification

The 10 pF and 60 pF values for the artificial antenna network of Figure B.1 are used to represent a conventional antenna, e.g., 1 m rod, 2 m coax. The 60 pF capacitor represents the capacitance of the coaxial cable between the vehicle antenna and the input of the vehicle radio.

NOTE Actual values with on-glass antennas and diversity systems may vary greatly.

B.2.1 Gain measurement

The **antenna matching unit** shall be measured to determine whether its gain meets the requirements of 5.1.2.1 using the test arrangement shown in Figure B.1.

B.2.2 Test procedure

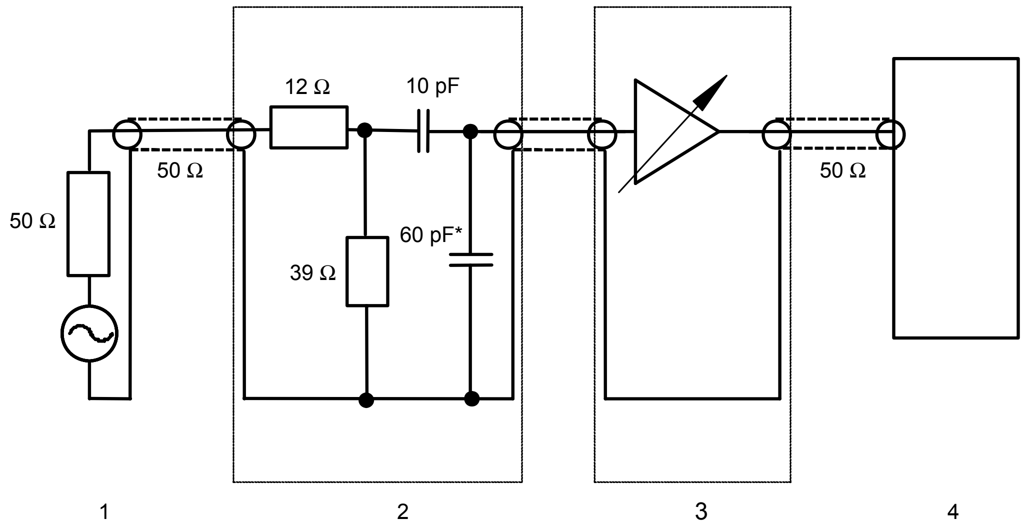
a) Set the signal generator 40 dB(μV) output level.

b) Plot the gain curve for each frequency segment.

NOTE For more precise calibration, the actual values of the components used in the artificial antenna network (AAN) and the input parameters of the matching network may be measured. The actual attenuation for the specific measuring equipment can be calculated and used to obtain the matching network gain with greater precision.

B.3 Impedance measurement

Measurement of the output impedance of the **antenna matching unit** with the antenna attached shall be made with a vector impedance meter (or equivalent test equipment). The output impedance shall lie within a circle on a Smith chart crossing (100 + j0) Ω, having its centre at (50 + j0) Ω (e.g. SWR less than 2:1).



Key

1 Signal generator

2 Artificial antenna network

3 Antenna matching unit

4 Measuring instrument

* Includes connector capacitance and, if used, cable capacitance

Figure B.1 –Verification set-up

Annex C
(informative)

Sheath-current suppressor

C.1 General

This Annex provides information on a proposed performance and verification of a sheath-current suppressor recommended for use when measuring vehicle antenna terminal voltage in the AM broadcast bands (LW, MW, SW). This suppressor electrically-isolates the ALSE from the vehicle ground.

C.2 Suppressor construction

The performance curve below (Figure C.1) shows the attenuation of the sheath currents using 20 turns of a coaxial cable around a ferrite toroidal core:

Material:	N30; AI = 5 400 nH
Size:	Toroidal core 58 mm × 40 mm × 17 mm
Manufacturer:	Siemens Order No.: B64290-A40-X830
Number of turns:	20 (coaxial cable)

NOTE To increase the attenuation, two sheath-current suppressors may be placed in series or more turns may be added to the single core.

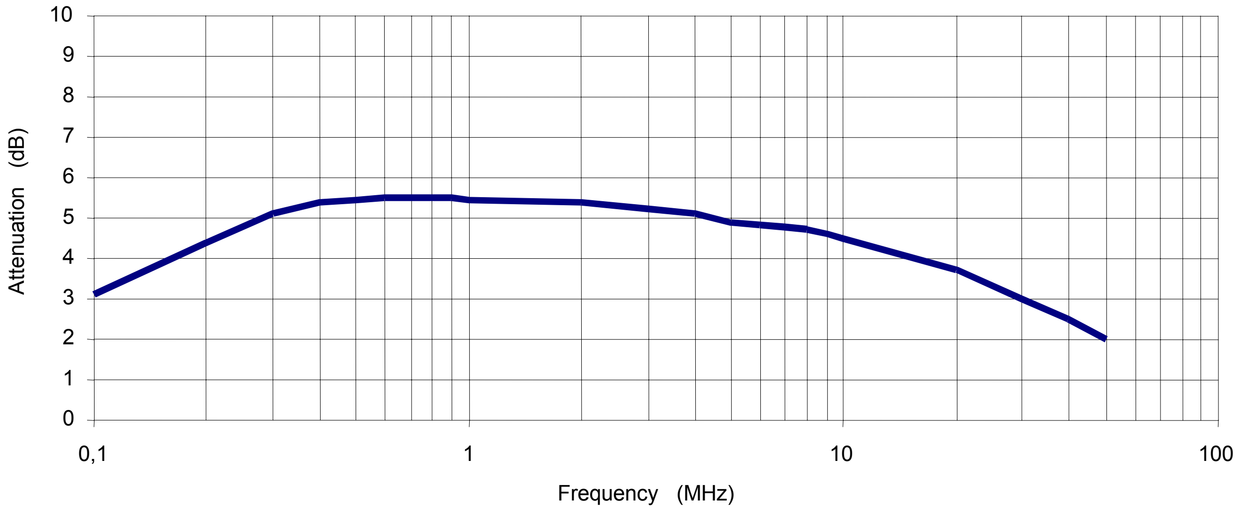


Figure C.1 – Attenuation vs. frequency

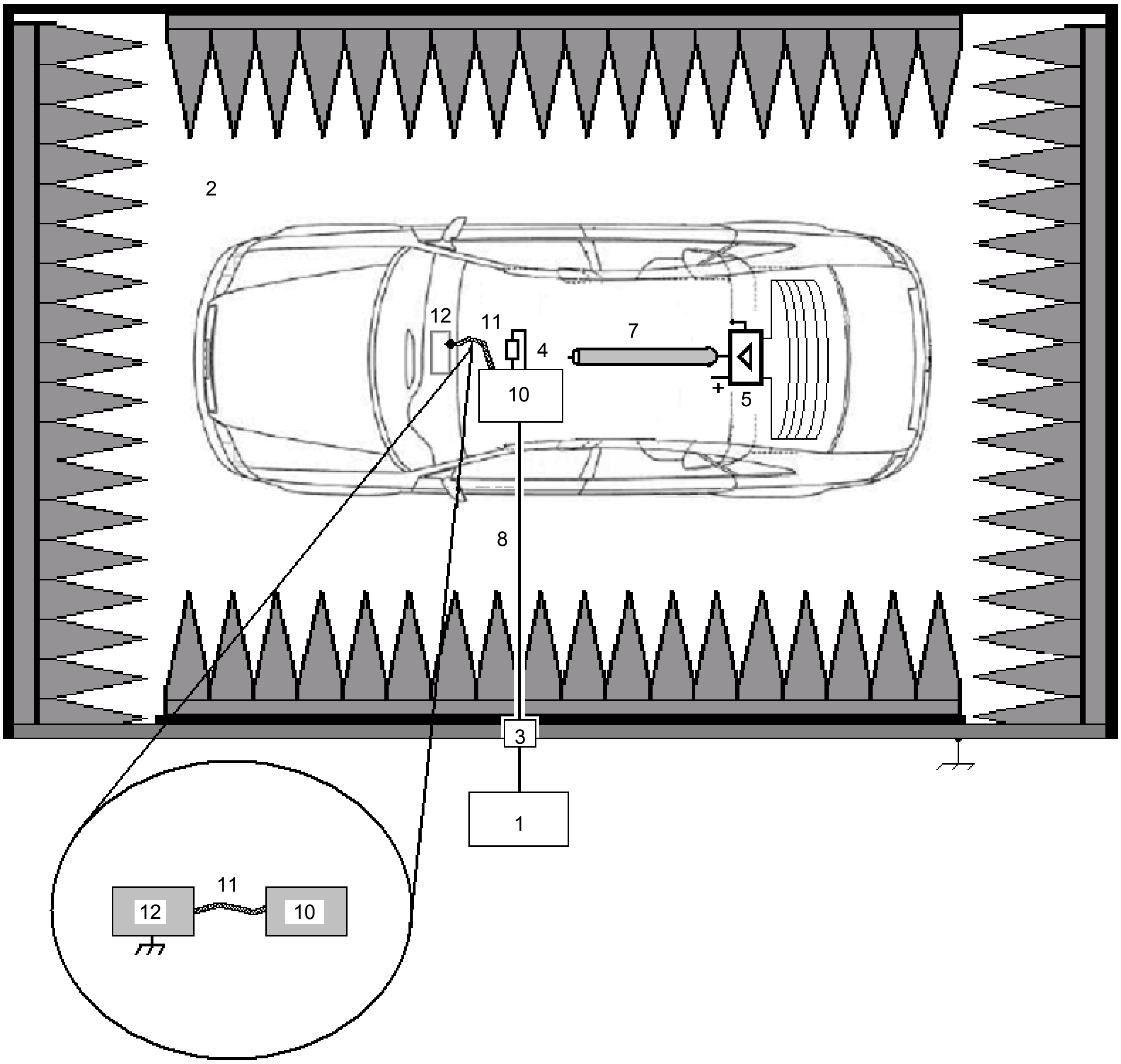
Annex D
(informative)

Guidance for the determination of the noise floor of active vehicle antennas in the AM and FM range

Three steps are necessary to determine the noise floor of an active antenna installed in the vehicle:

1) Measurement of the noise floor of the test equipment (measuring receiver plus impedance converter) with coaxial cable impedance termination at the impedance converter RF-input in the AM- and FM-range. ($U_{\text{Equipment noise}}$) (Test set-up see Figure D.1).
2) Measurement of the noise floor of the active vehicle antenna including the noise floor of the test equipment. ($U_{\text{Equipment noise plus antenna noise}}$)(Test set-up see Figure D.2).
3) Calculation of the active antenna noise floor with formula (D.1) (all terms in µV):

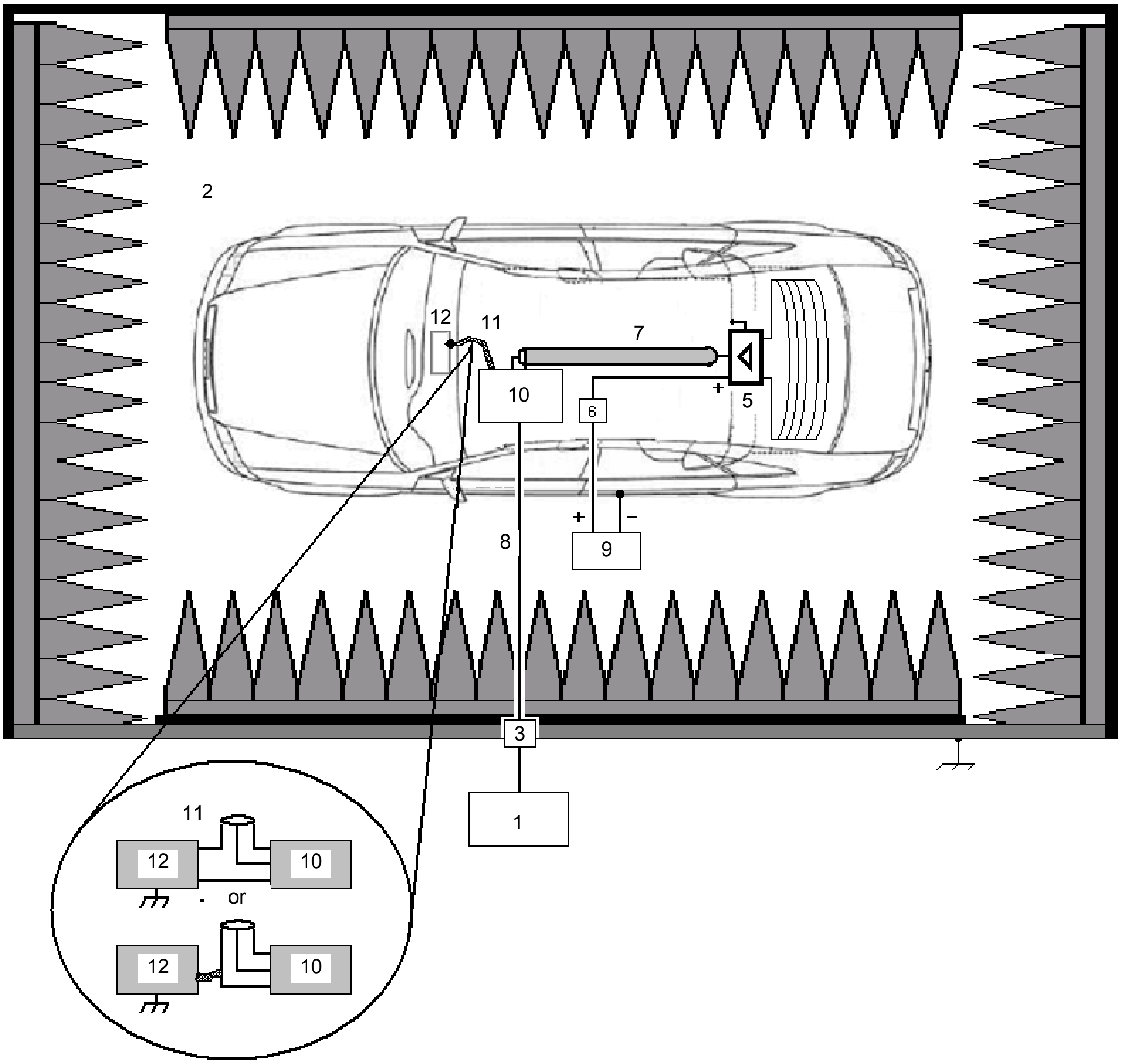
$$U_{Antenna\ noise} = \sqrt{U^2_{Equipment\ noise\ plus\ antenna\ noise} - U^2_{Equipment\ noise}} \tag{D.1}$$



Key

1	Measuring instrument
2	ALSE
3	Bulkhead connector
4	Resistor according to coaxial cable impedance
5	Vehicle antenna amplifier
-	
7	Antenna coaxial cable
8	High-quality double-shielded coaxial cable (50 Ω)
-	
10	Impedance matching unit
11	Short connection to the housing of the on-board radio
12	Housing of on-board radio

Figure D.1 – Vehicle test set up for equipment noise measurement in the AM/FM range



Key

1	Measuring instrument
2	ALSE
3	Bulkhead connector
-	
5	Vehicle antenna amplifier
6	Antenna amplifier power plug
7	Antenna coaxial cable
8	High-quality coaxial cable e.g. double-shielded (50 Ω)
9	External 12V battery
10	Impedance matching unit
11	Modified coaxial "T" connector or short connection to the housing of the on-board radio
12	Housing of on-board radio

Figure D.2 – Vehicle test set up for antenna noise measurement in the AM/FM range

Annex E
(normative)

Artificial network

The AN impedance Z_{PB} (tolerance ± 20 %) in the measurement frequency range of 0,1 MHz to 100 MHz is shown in Figure E.1. It is measured between the terminals P and B (of Figure E.2) with a 50 Ω load on the measurement port with terminals A and B (of Figure E.2) short-circuited.

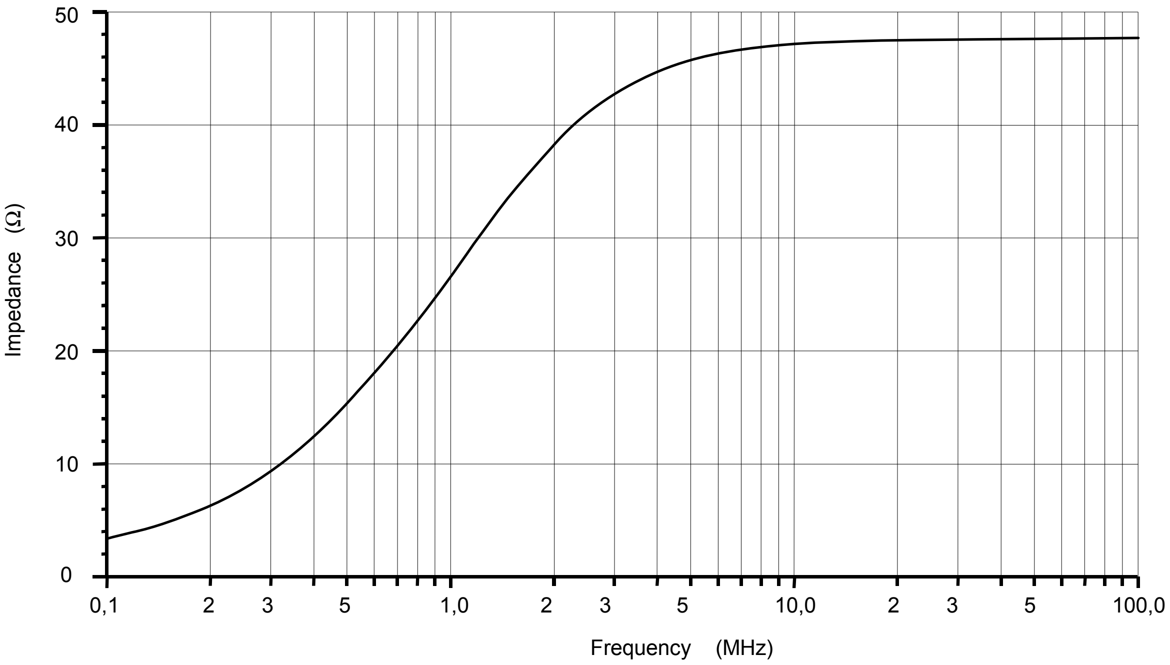


Figure E.1 – Characteristics of the AN impedance

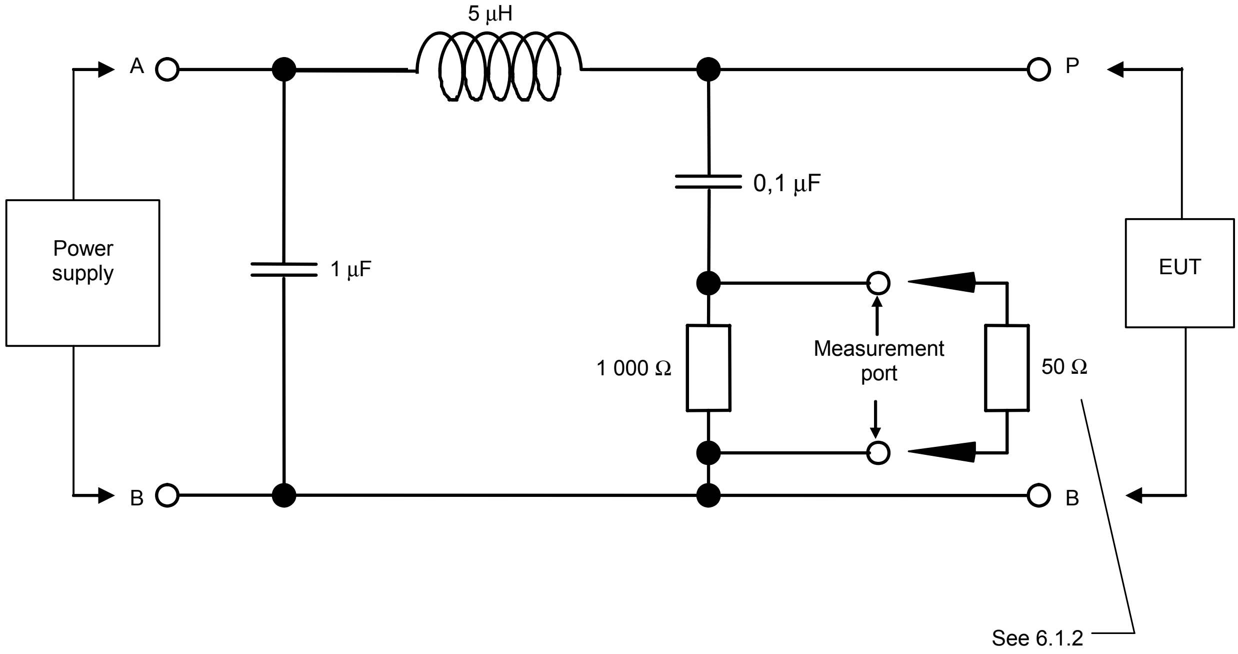


Figure E.2 – Example of 5 µH AN schematic

Annex F
(informative)

TEM cell dimensions

The dimensions of a TEM cell are shown in the Figure F.1 and given in Table F.1.

Dimensions in millimetres

Drawing not to scale

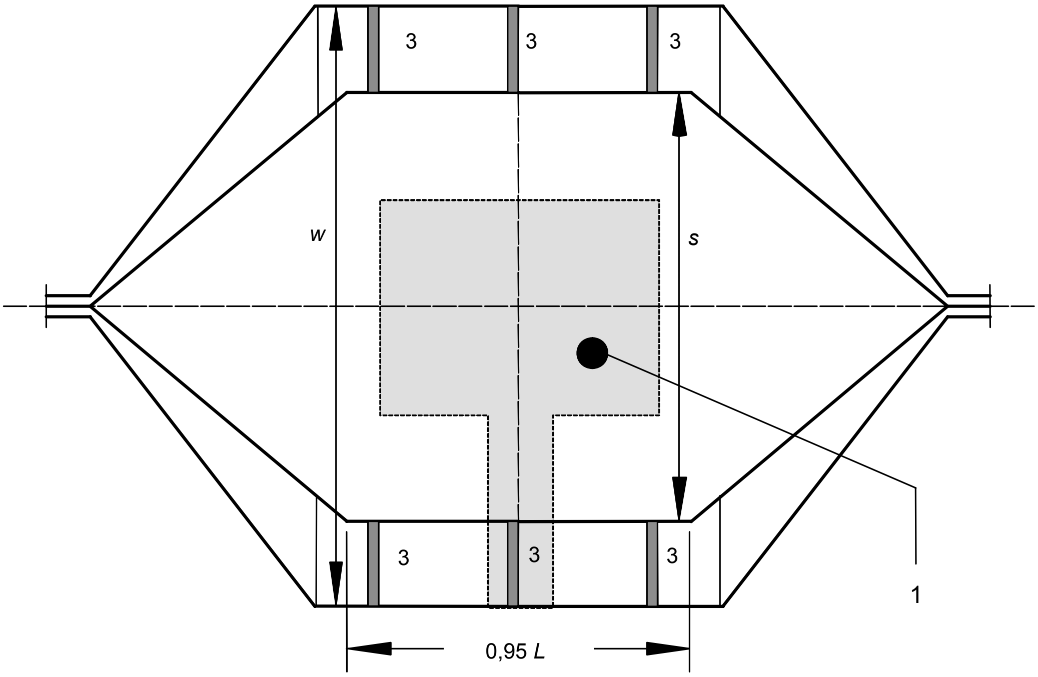


Figure F.1a – Horizontal section view at septum

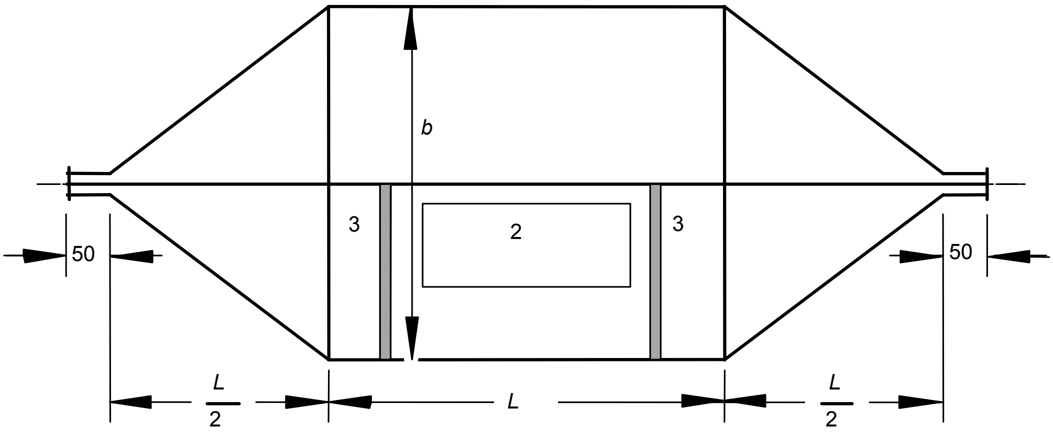


Figure F.1b – Vertical section view at septum

Key

1 Allowed working region: 0,33 *W*, 0,60 *L*

2 Access door

3 Dielectric supports

Figure F.1 – TEM cell

Table F.1 shows the dimensions for constructing TEM cells with specific upper frequency limits.

Table F.1 – Dimensions for TEM cells

Upper frequency MHz	**Cell form factor** *W*/*b*	**Cell form factor** *L*/*W*	**TEM cell height** ***b*** mm	**Septum width** ***S*** mm
100	1,00	1,00	1 200	1 000
200	1,69	0,66	560	700
200	1,00	1,00	600	500
300	1,67	1,00	300	360
500	1,50	1,00	200	230

NOTE The TEM cells in the box are typical for automotive component testing. For integrated circuit testing, even smaller TEM cells may be applicable for testing up to and above 1 GHz.

Annex G
(informative)

Radiated emissions from components/modules – Stripline method

G.1 General

The stripline is an open waveguide, which consists of a ground plane and an active conductor (septum) and has characteristic impedance. Commonly used values for characteristic impedances are 50 Ω and 90 Ω. Information relating to the size and construction of a stripline is given in Figure G.2 and Figure G.3.

Users are encouraged to study and experiment with the test method to increase the body of knowledge with the aim of reaching consensus on including it in the main body of this standard at a future date.

The stripline may be used in the frequency range from 150 kHz to 400 MHz where the harness is the primary radiating/coupling element.

The limits of the frequency range can be extended up to 1 000 MHz, if:

- the dominance of TEM mode can be shown [1];
- and the EUT is located under the septum;
- and the height of the EUT is limited to 1/3 of the septum height.

Measurements shall be made in a shielded enclosure to eliminate high levels of external disturbances. For further details see Figure G.1.

NOTE The influence of the shielded enclosure on the measured impedance (i.e. reflection coefficient as measured with a network analyser) of the stripline should be less than 6 dB compared with an open field test site. To realize this it might be necessary to equip the shielded enclosure partially with absorbers. An example is shown in Figure G.1.

G.2 Test set-up

For radiated emissions measurements, the arrangement of the EUT, test harness, load simulator and measuring equipment shall be equivalent to the example shown in Clause G.1.

Deviations of the location and length of the test harness (e.g. the original vehicle harness) and the location of the EUT have to be agreed between customer and supplier.

In order to achieve reproducible test results the EUT and the test arrangement shall be located at the same position in the stripline for each repeated measurement.

G.2.1 Stripline impedance matching

Correct impedance matching between the stripline and the measuring instrument of 50 Ω shall be maintained for all frequencies. This can be achieved by using lossless transmission line transformers (non-linear shape of the septum tapers or an additional external waveguide) or lumped passive network.

---

[1] For the design shown in figure G.2 it is presumed that the TEM mode is dominant up to 400 MHz. For the design shown in figure G.3 it is presumed that the TEM mode is dominant up to 1 000 MHz.

If the matching unit is a lumped passive network, appropriate correction of measurement results shall be made for any insertion loss.

G.2.2 Location of the EUT

The EUT shall be placed (50 ± 5) mm above the ground plane on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$) and shall be located on the same side as the 50 Ω load of the stripline as shown in Figure G.1. The case of the EUT shall not be grounded to the ground plane unless it is intended to simulate the real vehicle configuration. In the case that the EUT is not located under the septum, the EUT shall be located at a distance of $\left(200\ {}^{+50}_{\ \ 0}\right)$ mm from the edge of the septum.

G.2.3 Location and length of the test harness

The length of test harness parallel to the septum shall be (1 000 ± 50) mm.

The total length of the test harness between the EUT and the load simulator (or the **RF boundary**) is typical 1 700 mm and shall not exceed 2 000 mm. The same test harness can be used as with the ALSE test method (see 6.4).

The long segment of the test harness shall be within the inner one-third of the width of the septum. Ideally, it is placed under the centreline of the septum.

The wiring type is defined by the intended system application and requirement. The test harness shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), (50 ± 5) mm above the ground plane. The locations of the EUT and load simulator require a harness bend angle of (90 ± 15) degrees.

G.2.4 Location of the load simulator

The load simulator should be located at a distance of $\left(200\ {}^{+50}_{\ \ 0}\right)$ mm from the edge of the septum. If this cannot be met, the actual location of the load simulator shall be documented in the test report.

The load simulator shall be placed directly on the ground plane. If the load simulator has a metallic case, this case shall be bonded to the ground plane. Alternatively, the load simulator may be located adjacent to the ground plane (with the case of the load simulator bonded to the ground plane) or outside of the test chamber, provided the test harness from the EUT passes through an **RF boundary** bonded to the ground plane. When the load simulator is located on the ground plane, the d.c. power supply lines of the load simulator shall be connected through the AN(s) (see 6.1.2).

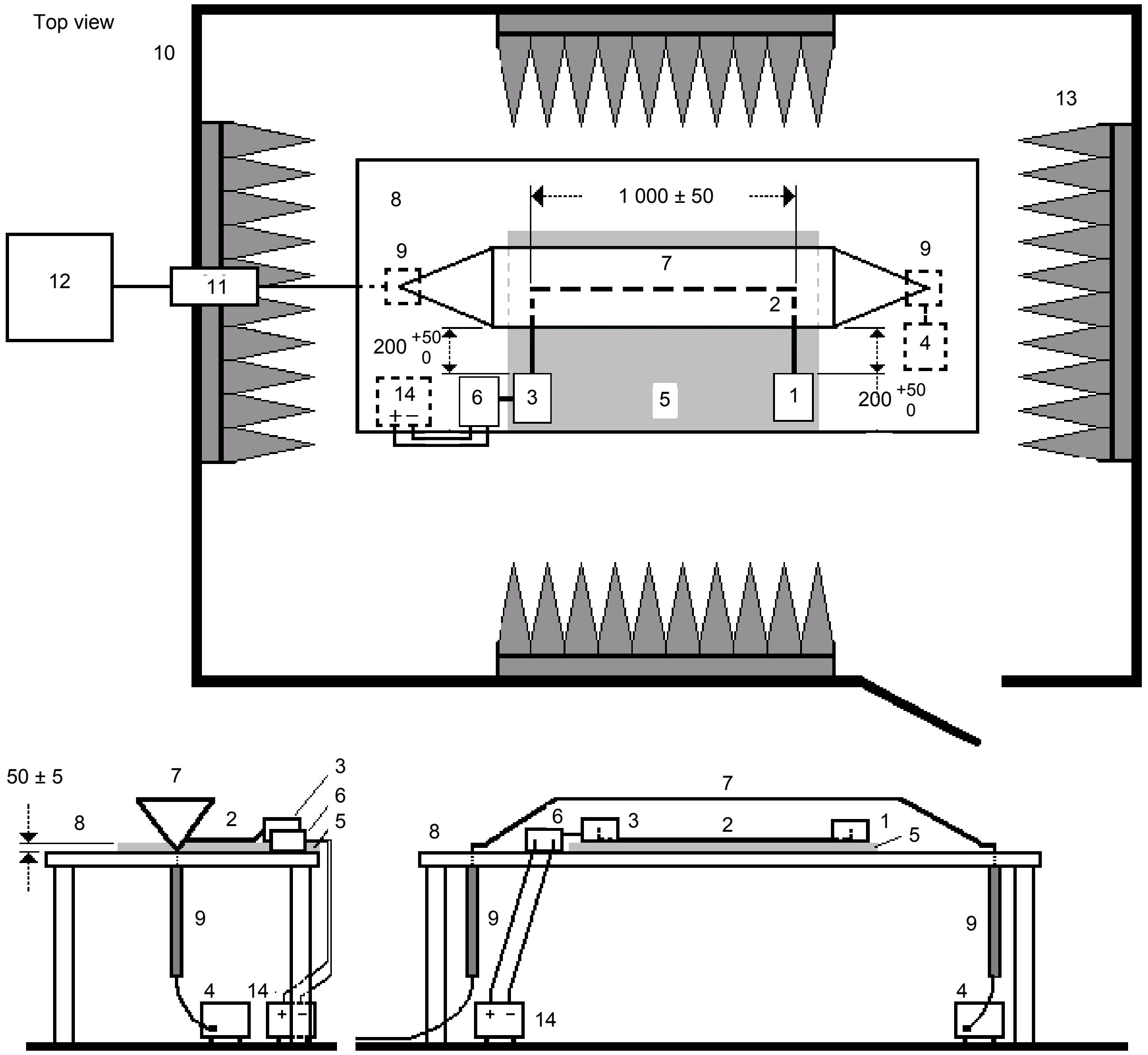
G.3 Test procedure

The general arrangement of the EUT, the harness and the peripherals, represents a standardized test condition. Any deviations from the standard test configuration shall be agreed between customer and supplier prior to testing and recorded in the test report.

The EUT shall be installed to operate under typical loading and operating conditions in the vehicle in such a way that the maximum emission state occurs. These operating conditions have to be defined in the test plan to ensure that customer and supplier are performing identical tests.

The arrangement of the EUT as well as the measuring equipment shall be functionally equivalent to the example shown in Figure G.1 and shall be defined in the test plan.

Dimensions in millimetres



Side view

Front view

Key

1	EUT
2	Test harness
3	Load simulator
4	50 Ω load (location optional)
5	Low relative permittivity support ($\varepsilon_r \le 1,4$)
6	Artificial network (AN)
7	Septum
8	Ground plane
9	Matching unit (if necessary)
10	Wall of shielded room
11	Bulkhead connector
12	Measuring instrument
13	Absorbers (if necessary)
14	Power supply (location optional)

Figure G.1 – Example of a basic stripline test setup in a shielded enclosure

G.4 Limits for radiated emissions from components/modules – Stripline method

Some disturbance sources are continuous emitters and require a lower limit than a disturbance source which operates only periodically or for short intervals.

The limits of the radiated electromagnetic energy may be different for each disturbance source and arrangement (coupling between antenna and electronic equipment in the vehicle).

For evaluation of radiated emissions from components/modules the RF voltage at the stripline output is to be measured.

Table G.1 – Examples of quasi-peak or peak limits for radiated disturbances – Stripline

Service / Band	**Frequency** MHz	**Levels** in **dB**(μV)									
		Class 1		**Class 2**		**Class 3**		**Class 4**		**Class 5**	
		Peak	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**	**Peak**	**Quasi-peak**
BROADCAST											
LW	0,15 - 0,30	87	74	77	64	67	54	57	44	47	34
MW	0,53 - 1,8	73	60	65	52	57	44	49	36	41	28
SW	5,9 - 6,2	65	52	59	46	53	40	47	34	41	28
FM	76 - 108	56	43	50	37	44	31	38	25	32	19
TV Band I	41 - 88	46	-	40	-	34	-	28	-	22	-
TV Band III	174 - 230	46	-	40	-	34	-	28	-	22	-
DAB III	171 - 245	40	-	34	-	28	-	22	-	16	-
TV Band IV/V	468 - 944	46	-	40	-	34	-	28	-	22	-
DTTV	470 - 770	50	-	44	-	38	-	32	-	26	-
DAB L band	1447 - 1494	Radiated emission – Stripline									
SDARS	2320 - 2345	Not applicable									
MOBILE SERVICES											
CB	26 - 28	64	52	58	46	52	40	47	34	41	28
VHF	30 - 54	56	43	50	37	44	31	38	25	32	19
VHF	68 - 87	50	37	44	31	38	25	32	19	26	13
VHF	142 -175	50	37	44	31	38	25	32	19	26	13
Analogue UHF	380 - 512	50	37	44	31	38	25	32	19	26	13
RKE	300 - 330	44	-	38	-	32	-	26	-	20	-
RKE	420 - 450	44	-	38	-	32	-	26	-	20	-
Analogue UHF	820 - 960	50	37	44	31	38	25	32	19	26	13
GSM 800	860 - 895	56	-	50	-	44	-	38	-	32	-
EGSM/GSM 900	925 - 960	56	-	50	-	44	-	38	-	32	-
GPS L1 civil	1567 - 1583	Radiated emission – Stripline Not applicable									
GSM 1800 (PCN)	1803 - 1882										
GSM 1900	1850 - 1990										
3G / IMT 2000	1900 - 1992										
3G / IMT 2000	2010 - 2025										
3G / IMT 2000	2108 - 2172										
Bluetooth/802.11	2400 - 2500										

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user shall select the appropriate bands over which to test. When the test plan includes bands that overlap the test plan shall define the applicable limit.

Table G.2 – Examples of average limits for radiated disturbances – Stripline

Service / Band	**Frequency** MHz	**Levels** in **dB**(µV)				
		Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**
		AVG	**AVG**	**AVG**	**AVG**	**AVG**
BROADCAST						
LW	0,15 - 0,30	67	57	47	37	27
MW	0,53 - 1,8	53	45	37	29	21
SW	5,9 - 6,2	45	39	33	27	21
FM	76 - 108	36	30	24	18	12
TV Band I	41 - 88	36	30	24	18	12
TV Band III	174 - 230	36	30	24	18	12
DAB III	171 - 245	30	24	18	12	6
TV Band IV/V	468 - 944	36	30	24	18	12
DTTV	470 - 770	40	34	28	22	16
DAB L band	1447 - 1494	Radiated emission – Stripline Not applicable				
SDARS	2320 - 2345					
MOBILE SERVICES						
CB	26 - 28	45	39	33	27	21
VHF	30 - 54	36	30	24	18	12
VHF	68 - 87	30	24	18	12	6
VHF	142 -175	30	24	18	12	6
Analogue UHF	380 - 512	30	24	18	12	6
RKE	300 - 330	30	24	18	12	6
RKE	420 - 450	30	24	18	12	6
Analogue UHF	820 - 960	30	24	18	12	6
GSM 800	860 - 895	36	30	24	18	12
EGSM/GSM 900	925 - 960	36	30	24	18	12
GPS L1 civil	1567 - 1583	Radiated emission – Stripline Not applicable				
GSM 1800 (PCN)	1803 - 1882					
GSM 1900	1850 - 1990					
3G / IMT 2000	1900 - 1992					
3G / IMT 2000	2010 - 2025					
3G / IMT 2000	2108 - 2172					
Bluetooth/802.11	2400 - 2500					

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user shall select the appropriate bands over which to test. When the test plan includes bands that overlap the test plan shall define the applicable limit.

These limits have been established for a 90 Ω stripline design as shown in Figure G.3. In case of using other stripline impedance characteristics than 90 Ω, the limits have to be adapted in accordance with the following formula G.1:

$$K_{\frac{90\Omega}{Z_2}} = 20\lg\sqrt{\frac{90\Omega}{Z_2}} \quad \text{dB} \qquad \text{(G.1)}$$

Example for a stripline with 50 Ω characteristic impedance:

$$K_{\frac{90\Omega}{50\Omega}} = 20\lg\sqrt{\frac{90\Omega}{50\Omega}} = 2{,}54\ \text{dB} \qquad \text{(G.2)}$$

Limits $Z_{50\Omega}$ = Limits $Z_{90\Omega}$ – $K_{90\Omega/50\Omega}$ = Limits $Z_{90\Omega}$ - 2,54 dB

where

K is the correction factor for limits in dB;

Z is the characteristic impedance of stripline in Ω.

G.5 Stripline design

An example of a 50 Ω stripline construction is shown in Figure G.2 and for a 90 Ω stripline in Figure G.3. The ratio of *b*/*h* determines the characteristic impedance. If dimension *b* is greater than *h*, the following equation G.3 applies:

$$Z = \frac{120\times\pi}{\frac{b}{h} + 2{,}42 - 0{,}44\times\frac{h}{b} + \left[1-\frac{h}{b}\right]^6} \qquad \text{(G.3)}$$

where

Z is the characteristic impedance of the stripline in Ω;

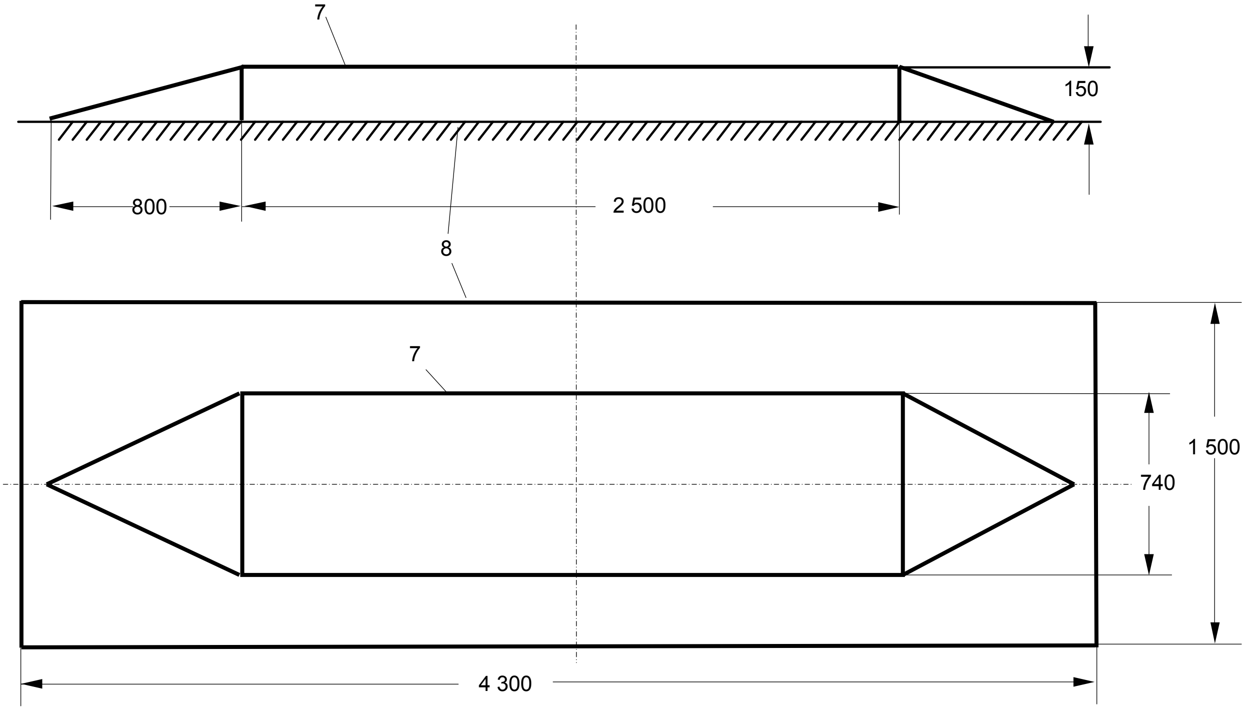
b is the stripline septum width in mm;

h is the stripline septum height above the ground plane in mm;

π = 3,14159.

NOTE Typical striplines are constructed to have an impedance of either 50 Ω or 90 Ω with b/h equal to 5 and 1,83, respectively. The termination may be either a resistive load or a tapered matching section terminated in a 50 Ω coaxial resistive load. A resistive load may be constructed of carbon resistors, conductive strips, thick film on a ceramic substrate, etc., in such a way that it matches the characteristic impedance of the stripline and minimizes the standing waves ratio.

Dimensions in millimetres

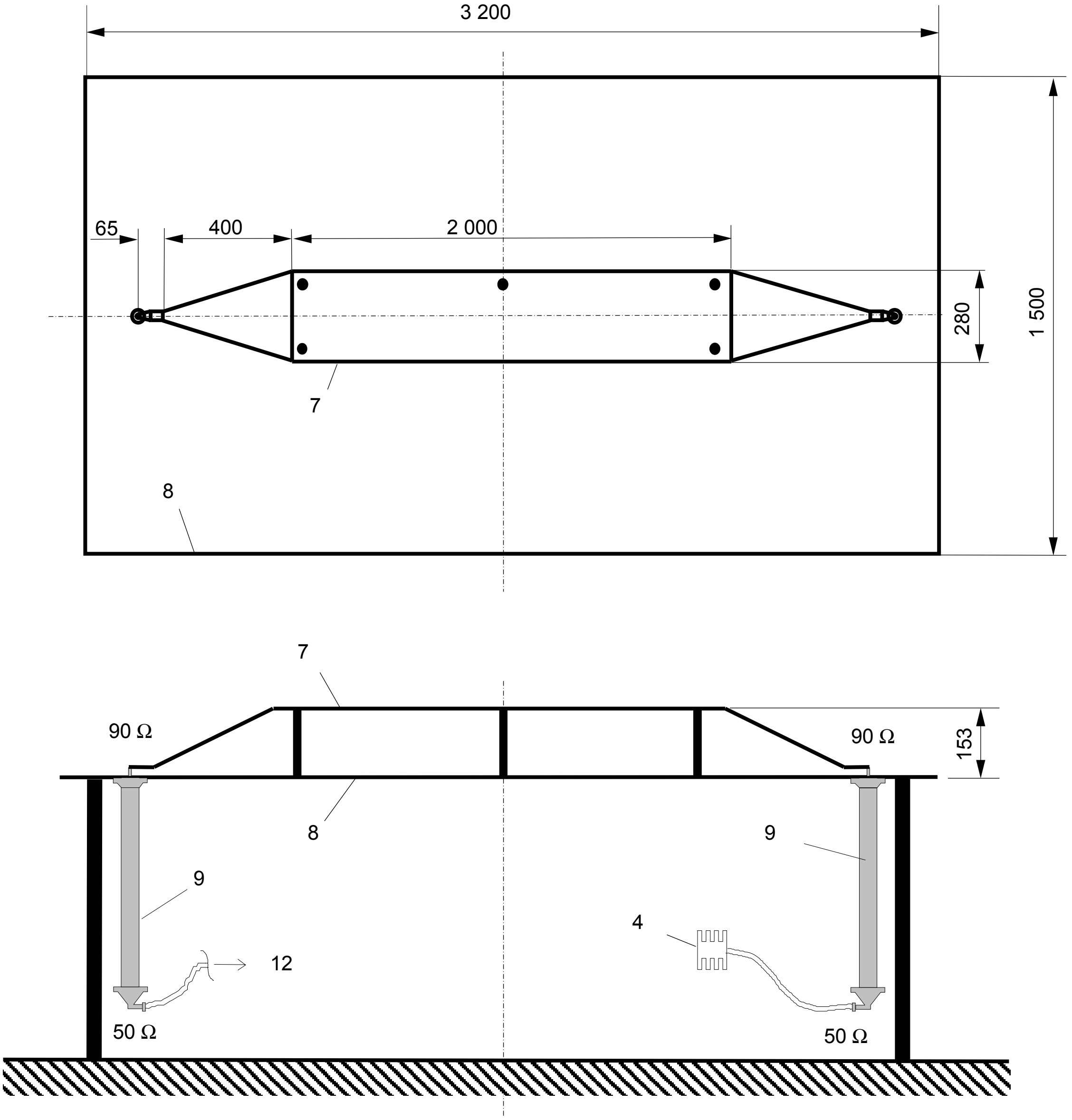


Key

7	Septum
8	Ground plane

Figure G.2 – Example for a 50 Ω stripline

Dimensions in millimetres



Key

4	50 Ω load
7	Septum
8	Ground plane
9	Matching unit
12	Measuring instrument

Figure G.3 – Example for a 90 Ω stripline

Annex H
(informative)

Interference to mobile radio communication in the presence of impulsive noise – Methods of judging degradation

H.1 Introduction

This annex provides methods of judging the degradation of radio communication in the presence of impulsive noise.

H.2 Survey of methods of judging degradation to radio channel

Test programs have been conducted in the United States of America by the Federal Communications Commission (FCC) and the Motor Vehicle Manufacturers Association (MVMA, later the American Automobile Manufacturers Association, AAMA, now disbanded). These test programs were directed toward providing a better understanding of the effects of motor vehicles on mobile communications reception.

The tests measured the degradation to communications systems subjectively and objectively at numerous receiver frequencies using several classes of automotive ignition noise sources such as a traffic stream and a controlled matrix of vehicles. Correlation between various objective and subjective measures of degradation was studied using rating scales employed by the FCC and MVMA for grading communication quality.

H.2.1 Subjective tests

H.2.1.1 Subjective tests of annoyance

Subjective degradation tests were conducted by the FCC using a single vehicle and groups of vehicles simulating traffic patterns. The FCC proposed and used a subjective jury rating scale based upon annoyance which had been used traditionally to determine the effects of ambient noise on job performance, accident rate, and fatigue of personnel.

Grade	Interfering effect was
5	almost nil
4	noticeable
3	annoying
2	very annoying
1	so bad the presence of speech was barely discernible

This grade system is very nearly the same as that given in ITU-R Recommendation ITU-R BS.1284 which should be used for future work if annoyance testing is conducted.

Quality		Impairment	
5	excellent	5	imperceptible
4	good	4	perceptible, but not annoying
3	fair	3	slightly annoying
2	poor	2	annoying
1	bad	1	very annoying

Annoyance is a highly subjective psychological reaction. The degree of annoyance caused by audible noise has been found to be influenced by a large number of variable physical and psychological factors (including illness, fatigue, status of interpersonal relations, and family problems).

H.2.1.2 Subjective tests of intelligibility

H.2.1.2.1 General

Since land mobile communication systems are used primarily to transmit voice messages, the performance of such systems should be based primarily on the intelligibility of the received signal in the presence of ignition noise.

The most common procedure for determining the intelligibility of a voice channel is a subjective method involving trained speakers and listener jury panels that directly score the percentage of speech that is intelligible. These schemes have the merit of producing repeatable results. Unfortunately, subjective scoring methods are expensive and time-consuming. As a result, they are not widely used.

The subjective scale for intelligibility proposed by the MVMA is:

Grade	Description
5	could understand the message extremely well
4	could understand the message fairly well
3	think I understood, but had to guess at some words
2	could barely discern the message
1	could not detect speech at all

H.2.1.2.2 Intelligibility test method

Beginning at 20 dB quieting with the vehicle ignition noise source off, the radio frequency input level was reduced by 1 dB decrements and scored at each decrement by the jury until the jury reached Grade 1 (worst). Then the radio frequency input level was increased by 1 dB increments until the 20 dB quieting level was again reached.

The radio frequency input level was then increased by 3 dB increments until the jury rated the quality Grade 5 (best). The radio frequency input level was then decreased by 3 dB decrements until the 20 dB quieting level was reached.

The entire process was repeated with the vehicle noise source in operation.

The results of the two tests (noise source off / noise source on) were then compared and the difference in radio frequency level for a particular quality grade (in decibels) was reported as the subjective degradation.

H.2.2 Objective tests

H.2.2.1 General

Uncertainty in subjective measurements arises from ambiguity of the rating scale definition, and variability of juror judgement. The latter source of error is largely caused by psychological factors. Objective measurements should have uncertainties less than those obtained from subjective tests.

A study carried out by the Institute for Telecommunication Sciences [1] develops a method of obtaining an objective intelligibility measure giving good results for speech sent through both analogue and digital noise-corrupted communication channels. The distortion measure is obtained using Linear Predictive Coding (LPC), a mathematical technique widely known for its application to the analysis and synthesis of speech.

H.2.2.2 Objective test method

To develop an objective intelligibility measure for corrupted speech, a comparison must be performed between the distorted speech and the original noise-free speech. A subjective intelligibility measure of the distorted speech must also be available in order to judge the quality of the objective measure being used. Both of these requirements are met by first making a noise-free master tape of preselected speech, then sending it through the voice communication channels to be tested and making a recording of the speech at the channel outputs. The latter recording can be subjectively scored for intelligibility, and also compared with the original speech by a mathematical technique to obtain an objective score.

The preselected speech to be sent over a voice channel for intelligibility scoring consists of phonetically balanced groups of isolated words, as opposed to complete sentences or nonsense syllables. These phonetically balanced words were used because subjective scores have been shown to be repeatable, which is a necessary criterion for this study. (During tests employing vehicles as a noise source, subjective scoring by listener panels was conducted and compared to the objective scores, resulting in good correlation.)

H.2.3 Conclusions relating to judgement of degradation

Numerous studies have been conducted over the years to develop a simple, inexpensive, objective method of measuring land mobile receiver degradation in the presence of ignition noise. Linear Predictive Coding (LPC) is neither simple nor inexpensive (when compared to the equipment used for CISPR 12 and CISPR 25 measurements), but it is technically a good objective method for measuring receiver degradation.

Subjective tests have proved to be effective in rating mobile receiver degradation. Of the two subjective rating methods in use, intelligibility was determined to be superior to annoyance in characterizing the effect of radio noise on a communication link. Most objective measurements taken during the subjective testing, however, showed poor correlation. The Linear Predictive Coding (LPC) method showed good correlation with the subjective intelligibility test method. Subjective tests are preferred, however, because of their reduced complexity and resulting lesser cost.

Considering only the subjective test methods, and as a result of the numerous tests conducted, it is recommended that intelligibility be used as the index of communications system performance rather than annoyance.

H.3 Reference document

[1] GAMAUF K. J. and HARTMAN W. J., *Objective Measurement of Voice Channel Intelligibility*, October 1977; available from the National Technical Information Service, Springfield, Virginia 22151, USA, reference number FAA-RD-77-153.

Annex I

(informative)

Items under consideration

I.1 Introduction

This annex contains future work items that are under consideration.

I.1.1 Peak, average, quasi-peak and CISPR average measurements and limits

As further work progresses in subcommittees CISPR A and CISPR H this will be reviewed and CISPR 25 updated accordingly.

I.1.2 Measurement uncertainty

This topic will be considered for future revisions of this standard.

I.1.3 Attenuation measurement method

The method of measuring the attenuation defined in Figure 5 needs to be defined.

I.1.4 Average measurements

Further precision is required when using a spectrum analyser to make average measurements i.e. small video bandwidth.

I.1.5 Chamber characterisation

A JTF has been initiated to study chamber characterization and correlation. The results of the study will be considered for a future edition.

Bibliography

CISPR 16-1:1999, *Specification radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus*

(*Continued from second cover*)

International Standard	*Title*
CISPR 16-1-2 : 2003	Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-2: Radio disturbance and immunity measuring apparatus — Ancillary equipment — Conducted disturbances
CISPR16-1-4 : 2007	Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-4: Radio disturbance and immunity measuring apparatus — Ancillary equipment — Radiated disturbances
CISPR 16-2-3 : 2006	Specification for radio disturbance and immunity measuring apparatus and methods — Part 2-3: Methods of measurement of disturbances and immunity — Radiated disturbances measurements
ISO 11452 : 2005	Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Bulk current injection (BCI)
SAE ARP 958.1 Rev D:2003-02	Electromagnetic interference measurement antennas; Standard Calibration Method

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